Grid Column Number (X)	Grid Row (Y)						
	1	2	3	4	5	6	7
1	4,100	6,200	7,200	10,300	200	0	0
2	7,800	8,700	9,400	11,800	100	0	0
3	8,100	10,500	15,600	10,500	200	0	0
4	10,700	12,800	13,800	15,600	400	0	0
5	11,500	13,900	14,500	13,700	600	0	0
6	9,300	14,900	13,700	10,200	1,200	0	0
7	10,100	12,600	16,700	15,800	12,400	2,600	0
8	8,800	13,700	15,200	14,100	10,800	17,200	500
9	5,300	16,700	13,800	11,900	13,500	18,600	12,000
10	5,100	17,400	10,300	9,800	10,300	15,500	11,700
11	7,700	9,200	7,500	8,500	7,800	9,900	8,700
12	4,300	6,700	5,800	6,800	5,400	7,100	6,400
Totals	92,800	143,300	143,500	139,000	62,900	70,900	39,300

Table 1 Estimated Population by 2.5-mile Square Grids in the Cleveland Area

other costs for the existing locations are given in Table 2. For planning purposes, it was estimated that annual rental rates would be $22 per sq. ft., staff salaries would average $21,000 per year including benefits, and utilities would annually average $4 per sq. ft. The site space needed would be a minimum of 1,500 sq. ft. and additional space of 500 sq. ft. for each 100,000 of population served in excess of 100,000. A minimum of four staff persons would be needed, with an additional person for each 100,000 persons above the initial 100,000 served. Dan thought that a center-of-gravity type of location methodology might be used to deal with his planning questions.

Closing an existing site would involve moving equipment and paying separation expenses to any staff who could not be

Table 2 Current Bureau Locations and Associated Statistics

No.	Bureau	Grid Row Number	Grid Column Number	Size, sq. ft.	Staff, Persons
1	Cleveland-Brooklyn	3.0	5.2	1,700	4
2	Cleveland-University Circle	5.5	7.8	1,200	4
3	North Olmsted	2.5	1.2	2,000	5
4	Berea	1.3	2.7	1,800	4
5	Parma	1.5	5.9	1,500	4
6	Lakewood	4.4	4.1	2,200	5
7	Euclid	6.9	9.0	2,700	5
8	Mayfield Heights	5.5	11.2	1,500	5
	Totals			14,600	36

transferred to other locations. Equipment moving would amount to $10,000 for each site, and separation expenses would be approximately $8,000 per staff member, if any existing positions were to be eliminated. These would be one-time expenses. For planning purposes, any unused equipment would be considered valueless and given to charity. To open a new site beyond the current eight bureaus would require the acquisition of new equipment ($60,000), if another site were not being closed so that equipment could be transferred. Initial hiring costs for staff not being transferred would be $3,000.

Dan was perplexed by the value that residents placed on bureau location. Since residents used their own means of transportation and rarely expressed their level of satisfaction with the effect of bureau location, there was no direct way to determine the benefits of location. However, he figured that the residents incurred a cost of travel and their proximity to bureaus was important. Based on the average number of trips residents made to the bureau, the cost of transportation, and the proportion of the population using the bureaus, an estimate of the annual travel cost between resident and a bureau location was 12¢ mile per resident. The territorial coverage of the current bureaus was not known. ■

QUESTIONS

1. Do you think there is any benefit to changing the network of license bureaus in the Cleveland area? If so, how should the network be configured?
2. Do you think that Dan Rogers's study approach is sound?
3. What concerns, besides economic ones, should Dan have before suggesting any network changes?

Southern Brewery

Southern Brewery is a regional brewer of a line of beer products. Markets for its products are limited to the southeastern portion of the United States, as shown in Figure 1. Southern's beers are local favorites and demand is growing rapidly among consumers over the age of 50. Its products are slightly lower in alcoholic content and are considerably lower in calories than the more popular brands. They are promoted as a healthy choice, and consumers are responding with increasing patronage.

To meet the growing demand for its products, Carolyn Carter, the director of logistics, has been asked to evaluate the effect on operating costs of constructing a brewery at Jacksonville, Florida. This proposal is brought about by the rapid growth in the southernmost markets of its region, and the projected strain on the Montgomery brewery's capacity. Carolyn begins her analysis by noting that the existing breweries at Richmond, Virginia, Columbia, South Carolina, and Montgomery, Alabama, vary in their costs and production capacities. The cost to produce a barrel of beer products is different among these locations, based on variations in equipment age; local labor rates; delivered costs of raw materials to breweries; and miscellaneous cost differences resulting from local property taxes, insurance rates, and utilities. These costs and capacities are summarized in Table 1. Each brewery produces a complete product line.

Southern maintains a uniform delivered price to distributors of $280 per barrel throughout its marketing region. Current average

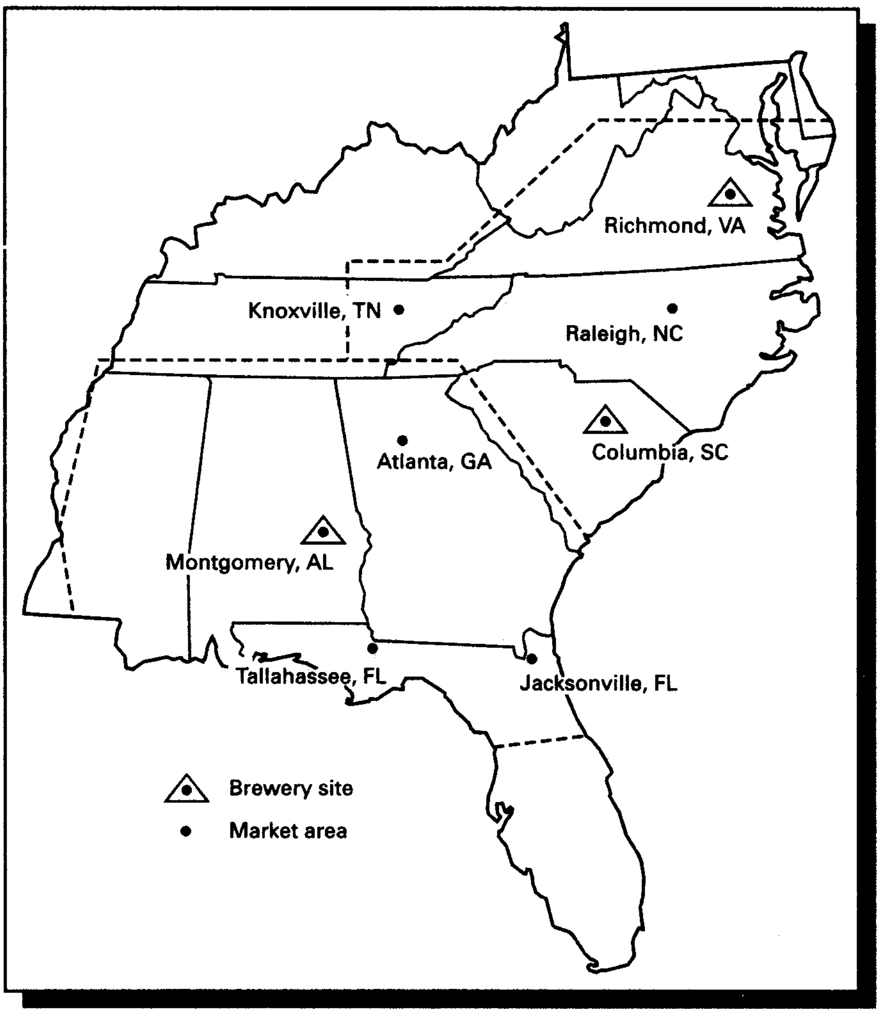

Figure 1 Map of Southern Brewery's Plants and Market Regions

Table 1 Production Costs and Capacities at Southern's Three Breweries

Brewery Location	Production Cost, $ per Barrel	Annual Production Capacity, Barrels[a]
Richmond, VA	$140	100,000
Columbia, SC	145	100,000
Montgomery, AL	137	300,000

[a] A unit of annual capacity is estimated to be currently worth (could be sold for) $50 per barrel.

Table 2 Current Average Annual Sales by Market Area and Brewery of Origin

	Market Area	Brewery of Origin	Annual Sales, Barrels
1	Richmond, VA	Richmond, VA	56,000
2	Raleigh, NC	Richmond, VA	31,000
3	Knoxville, TN	Columbia, SC	22,000
4	Columbia, SC	Columbia, SC	44,000
5	Atlanta, GA	Montgomery, AL	94,000
6	Savannah, GA	Montgomery, AL	13,000
7	Montgomery, AL	Montgomery, AL	79,000
8	Tallahassee, FL	Montgomery, AL	26,000
9	Jacksonville, FL	Montgomery, AL	38,000
		Total	403,000

annual sales from each brewery for each market area are given in Table 2. A profit margin of 20 percent is earned on sales.

Transportation between the breweries is handled by a private trucking fleet owned by Southern. From the records of truck and driver expenses and the deliveries made, Carolyn constructed the average transport costs shown in Table 3. Based on her experience with the other breweries, Carolyn estimates the transport costs for the proposed breweries.

The primary reason for suggesting a new brewery at Jacksonville is the approximate doubling of the Florida market, whereas the remaining markets are anticipated to grow between 15 and 50 percent. It is thought that the Jacksonville brewery would relieve the Montgomery brewery from serving the Florida market. The anticipated five-year demand pattern for each market area and the serving brewery is shown in Table 4.

A brewery at Jacksonville with a capacity of 100,000 barrels is planned. To construct a brewery of this size is expected to cost $10,000,000, with a useful life of 15 years. The company's expectation for such a project is a 20 percent

Table 3 Delivery Costs Between Breweries and Market Areas in Dollars per Barrel

		Breweries			
	Market Area	Richmond	Columbia	Montgomery	Jacksonville[a]
1	Richmond	$ 8.49	$12.54	$19.98	$17.13
2	Raleigh	10.70	9.78	16.35	14.25
3	Knoxville	16.38	12.81	13.80	15.48
4	Columbia	12.54	6.96	12.93	11.16
5	Atlanta	15.48	11.85	10.20	13.80
6	Savannah	14.64	9.54	13.80	9.54
7	Montgomery	19.98	12.93	6.96	13.80
8	Tallahassee	24.30	15.18	13.65	9.72
9	Jacksonville	18.84	12.27	15.18	7.68

[a] Proposed brewery

Table 4
Projected Fifth-Year Average Annual Sales by Market Area and Proposed Brewery of Origin

	Market Area	Brewery of Origin	Annual Sales, Barrels
1	Richmond, VA	Richmond, VA	64,000
2	Raleigh, NC	Richmond, VA	35,000
3	Knoxville, TN	Columbia, SC	33,000
4	Columbia, SC	Columbia, SC	55,000
5	Atlanta, GA	Montgomery, AL	141,000
6	Savannah, GA	Montgomery, AL	20,000
7	Montgomery, AL	Montgomery, AL	119,000
8	Tallahassee, FL	Jacksonville, FL; Montgomery, AL; and Columbia, SC	52,000
9	Jacksonville, FL	Jacksonville, FL	76,000
		Total	595,000

return before tax, and sales expenses and overhead are approximately 27 percent of sales. The new brewery is believed to be able to produce at a cost of $135 per barrel. ■

QUESTIONS

1. If you were Carolyn Carter, would you agree with the proposal to build the new brewery? If you do, what plan for distribution would you suggest?
2. If the new brewery is not to be constructed, what distribution plan would you propose to top management?
3. What additional considerations should be taken into account before reaching a final decision?

Technical Supplement

This is the model formulation to the problem shown in Figure 13-5.[55]

$$\text{Minimize} \sum_{ijkl} \underbrace{C_{ijkl}}_{\boxed{\text{Inbound and outbound transport rates}}} X_{ijkl} + \sum_{k} \left[\overbrace{f_k}^{\boxed{\text{Fixed costs}}} z_k + \overbrace{v_k}^{\boxed{\text{Handling rate}}} \sum_{l} \left(\underbrace{\sum_{i} D_{il}}_{\boxed{\text{Sum of demand for a customer } l \text{ across all products}}} \right) y_{ki} \right]$$

subject to:

Available production capacity cannot be exceeded

$$\sum_{kl} X_{ijkl} \le \overbrace{S_{ij}}^{\boxed{\text{Plant capacity}}} \quad \text{for all } ij$$

All customer demand must be met

$$\sum_{j} X_{ijkl} = \overbrace{D_{il}}^{\boxed{\text{Customer demand}}} y_{kl} \quad \text{for all } ikl$$

Each customer must be served by a single warehouse

$$\sum_{k} y_{kl} = 1 \quad \text{for all } l$$

Keep warehouse throughput between minimum throughput $\underline{V}_k$ and capacity $\overline{V}_k$

$$\overbrace{\underline{V}_k}^{\boxed{\text{Minimum warehouse throughput}}} \le \sum_{l} \left(\sum_{i} D_{il} \right) y_{kl} \le \overbrace{\overline{V}_k}^{\boxed{\text{Warehouse capacity}}}$$

and

$$\text{All } X \ge 0$$
$$\text{All } y = 0 \text{ or } 1$$
$$\text{All } z = 0 \text{ or } 1$$

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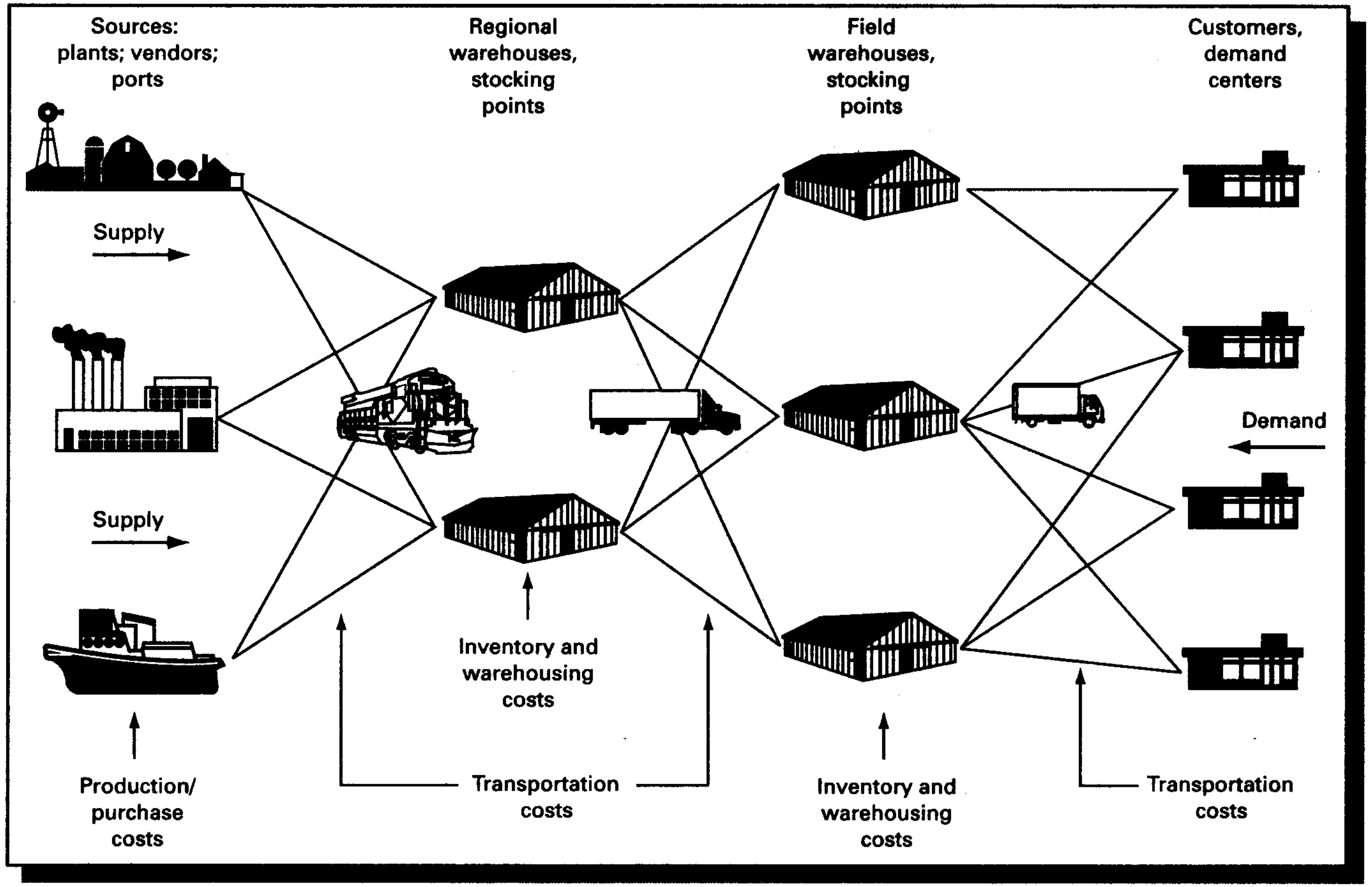
[55] Based on A. M. Geoffrion and G. W. Graves, "Multicommodity Distribution System Design by Benders Decomposition," *Management Science*, Vol. 20, No. 5 (January 1974), pp. 822–844.

where

i = index for commodities
j = index for plants
k = index for possible warehouses
l = index for customer zones
S_{ij} = supply (production capacity) for commodity i at plant j
$\underline{D}_{il}$ = demand for commodity i in demand zone l
$\underline{V}_k, V_k$ = minimum, maximum allowed annual possession and operating cost for warehouse at site k
f_k = fixed portion of the annual possession and operating costs for a warehouse at site k
v_k = variable unit cost of throughput for a warehouse at site k
C_{ijkl} = average unit cost of producing, handling, and shipping commodity i from plant j through warehouse k to customer zone l
X_{ijkl} = variable denoting the amount of commodity i from plant j through warehouse k to customer zone l
y_{kl} = a 0–1 variable that will be 1 if warehouse k serves customer zone l, and 0 otherwise
z_k = a 0–1 variable that will be 1 if warehouse k is open, and 0 otherwise

Figure 14-1 Generalized Product Flow Network



the warehousing for local telephone operations, but remained with AT&T after divestiture. The new telephone companies, each with revenues that ranged from $500 million to $700 million per year, were ordered out of the existing Western Electric warehouses, leaving the new companies without a logistics network to supply parts, components, and supplies to local installers. The first order of business was to configure logistics networks of warehouses, inventories, and trucking routes and schedules to meet the service requirements for each of the new, emerging telephone companies. Each telephone company conducted a network configuration study.

Sakuma Exports is a leading player in the export of agricultural commodities and merchandise in India. The product basket includes agro-based commodities like sugar, onions, peanuts, and chilly. It exports 25 commodities to over 75 countries. The company has a network of over 400 suppliers and has developed logistics from nine ports and inland container depots (ICDs). So, Sakuma needs to be very particular about developing supply chain and logistics network configuration.[1]

Network configuration cannot be limited to the forward movement of goods from suppliers to customers since, in some cases, firms must take back from downstream locations items such as packaging materials (e.g., pallets), leased products (e.g., copy machines), damaged goods (e.g., replaced auto engines), and products to be reworked and resold (e.g., disposable cameras). This reserve network often overlays the forward network and must be integrated into it. Network planning is complicated when the forward and reverse channels cannot be separated due to shared facilities.

The problem of network configuration is of great importance to top management. It is common that redesigning the logistics network can generate annual savings from 5 to 15 percent of total logistics costs. When we consider a company such as the Whirlpool Corporation that annually spends $1.5 billion on logistics, a 10 percent savings results in $150,000,000 per year. With cost reductions of this magnitude, it is not difficult to see why network reconfiguration tops the list of planning issues. This, of course, is in addition to the benefits that network design can have on customer service and the improved competitiveness of the firm.

DATA FOR NETWORK PLANNING

A Data Checklist

Network planning can require a substantial database that is derived from many sources. Although some data may be specific to a particular network configuration problem, much of the database can be generalized. It can include

- A listing of all products in the product line
- Locations of customers, stocking points, and source points
- Demand for each product by customer location
- Transportation rates or costs
- Transit times, order transmittal times, and order-fill rates

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[1] Available at http://www.sakumaexportsltd.com.

- Warehousing rates or costs
- Production/purchase costs
- Shipment sizes by product
- Inventory levels by location by product and the methods to control them
- Order patterns by frequency, size, season, and content
- Order-processing costs and where incurred
- Capital cost
- Customer service goals
- Available equipment and facilities with capacity limitations
- Distribution patterns of how sales are currently met

Data Sources

Most firms do not have formalized logistics information systems that specifically generate the data needed for logistics planning of the type just listed. This leaves the logistician to acquire the needed data from a variety of sources both internal and external to the firm. Primary sources for such data include business operating documents, accounting reports, logistics research, published information, and judgment.

Business Operating Documents

Every firm generates many documents to manage the various aspects of the business. Some of these may be related to logistics activities, but many are prepared for other purposes. They also may simply provide data, but not information, that is directly useful for planning. Let us examine some of these documents, beginning with the sales order.

The sales order, and its attendant documentation, is a primary data source from which a variety of essential logistics information can be derived. Customer locations, product sales levels over time by location, terms of sale, serving locations, shipment sizes, stock status and order-fill rates, and customer service levels are just a few of the kinds of information that can be derived from the sales order processing system. It is very common for companies to store such data in computers. This aids in their extraction and manipulation into information needed for planning.

Application

To complete a warehouse location study, a specialty chemical company was asked by its management consultant to provide data about sales throughout the country by chemical and paint products, and further to break out the sales data by large and small accounts. Since the company retained all of its sales transactions in a computer database, this database could be searched and sorted to provide the necessary sales data for an entire year. Further, the sales transactions could be cross-linked to a customer file that contained U.S. postal zip codes. Collecting contiguous zip codes into about 200 sales regions allowed sales to be aggregated into a manageable number of territories. This was all done without the need for any manual handling of the data.

Selling, manufacturing, purchasing, shipping, storing, and handling are all primary activities that firms conduct on a regular basis. Since they are to be measured and controlled, reports are frequently issued about their status. The logistician utilizes these reports to generate basic information about activity levels. For example, if we were interested in the percentage of shipments from a warehouse made in particular weight breaks, the freight bills or a report containing individual shipments, charges, and the carrier used might be appropriate sources for such data. These raw data can be transformed into a frequency distribution of shipment sizes.

Although it would be impractical here to examine all the activity reports and documents generated in the normal course of business operations, it is fair to say that business documents are a rich source for much of the data that the logistician needs for network planning. It is also worth noting that additional data are available from informal reports that individuals within the company generate for their own use.

Accounting Reports

Accounting data are also an important source of internal information available to the logistician. Accounting data focus on identifying the operating costs, including the costs for logistics activities.

Accounting practice, in general, does an excellent job of reporting on a majority of logistics costs. However, much of accounting practice is directed toward shareholder interests and not those of the manager. This is particularly true for logistics network planning. Within the guidelines of accepted accounting practice, some important costs go unreported, such as inventory-holding costs and the cost of inventory obsolescence. Others are reported in a manner that is confusing to the planning process. That is, should the line item cost for trash collection in a warehouse accounting report be categorized as a fixed, storage, or handling cost? Nevertheless, such accounting reports remain the primary source for cost data.

Logistics Research

Research provides information that neither an operating order-processing system nor an accounting system is likely to generate. Although there is little formal logistics research carried out by companies, such effort can be worthwhile in the defining of the basic relationships useful for network planning, such as sales-service relationships and transport rate-distance relationships. When such research is carried out, it is common for it to be conducted by internal or external consulting groups and by university professors.

Logistics research may also be conducted indirectly on behalf of the firm. Trade associations such as the Council of Logistics Management[2] and the Warehouse Education Research Council[3] regularly sponsor research efforts and report the results in publications distributed to members as well as nonmembers. It is a valuable source of logistical data about other firms in the same industry, and other industries. Such data enhance or supplement the data from the previously noted sources.

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[2] www.CLM1.org.

[3] www.WERC.org.

Published Information

Much secondary, and sometimes primary, data are available to the logistician from outside the company. Trade magazines,[4] government-sponsored research reports,[5] and academic journals[6] are examples of sources of information on cost and industry trends, technological advances, activity levels, and forecasts.

Judgment

Executives within the firm, consultants to the firm, sales staff, operating personnel, and suppliers to the firm all represent data sources and are part of the logistics database. Little investment is typically needed to unlock this readily available data source.

Data Encoding

Data handling is facilitated by several techniques that have been used to code data. Chief among these are product coding and geographic coding.

Product Coding

Computer technology, the laser, and holography have brought about a way to enter data into computer memory banks without the necessity of manual entry. Bar codes, now popular for data entry, allow products, cartons, and shipments to be identified by the optical scanning of a numbering system. This facilitates the rapid and accurate transfer of data as well as its manipulation by sorting, selection, and rearrangement into information needed for planning. Particular attention should be paid to designing the code that potentially provides the data useful for planning as well as for operations.

Geocoding

Sales data are typically collected by a firm on a by-customer basis with reference to customers by name and address. Network planning is facilitated if sales data are referenced to a geographic base rather than an accounting base. Analysis for transportation decisions, facility location decisions, and inventory decisions are all enhanced by such a geographic database.[7] To the network planner, a customer account is a location, and a distance from other accounts. Preferably, logistics data should be referenced to a geographic customer code.

Geographic coding of data can be accomplished in several ways. A simple approach is to place a linear grid overlay on a map and use the horizontal and vertical grid numbers as the code. For example, a grid overlay is placed on a map of

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[4] For example, *Transportation & Distribution, Distribution, American Shipper, Inbound Logistics, Warehousing Management, Modern Materials Handling, Traffic Management*, and *Transport Topics*.

[5] For example, RAND reports and the many reports available from the Superintendent of Documents, Washington, DC.

[6] For example, *Journal of Operations Management, Transportation Journal, Management Science, Logistics and Transportation Review, International Journal of Physical Distribution and Materials Management, IIE Transactions, Journal of Business Logistics*, and *International Journal of Logistics Management*.

[7] A time-related database is also an important basis on which to collect data. One can argue that customers are more interested in time dimensions of service rather than geographic dimensions and that network design should be based on time. However, networks are more practically designed around a geographic dimension.

Europe, as shown in Figure 14-2. Many maps give latitude and longitude coordinates that may be used as well, or these coordinates may be found by using a global positioning system locator device. Customers and sales data are then located within the various cells defined by the grid. That is, a customer account located within the cross-hatched cell would be aggregated along with other accounts falling within the cell. All are treated as if located at the midpoint or at the centroid of the cell. The location code for this point would be 008011, as shown in Fig. 14-2, which is a combination of horizontal and vertical coordinates. All data would be referenced to this and similar numbers, as shown in Table 14-1.

Figure 14-2 A Simple Linear Grid Placed Over a Map of Western Europe

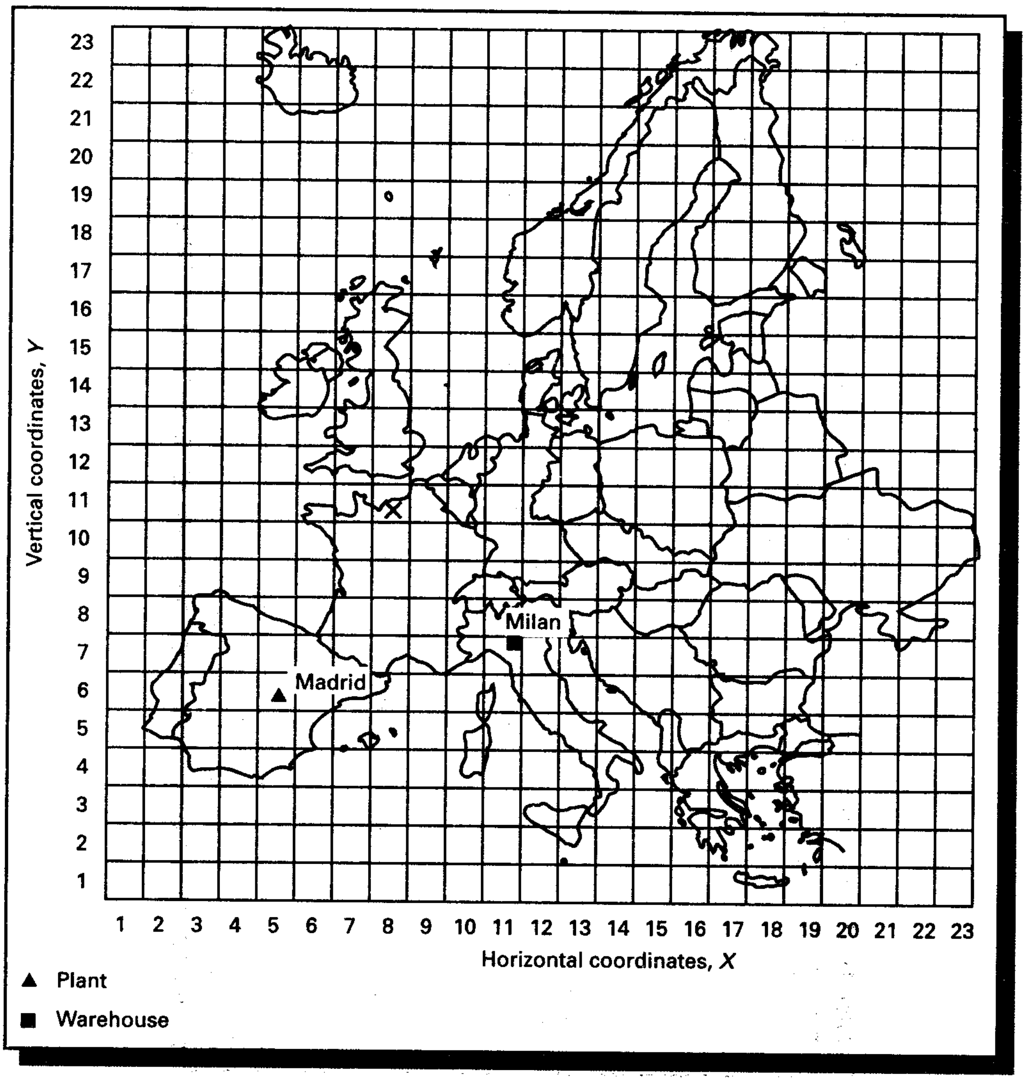

Table 14-1 An Example of Hypothetical Sales Order Data Summarized Around a Grid Location Code

Customer Grid Location Cell Code[a]	No. of Accounts in Cell	Total Annual Sales	Total Annual Shipping Weights	Average Order Size, Units	Average Customer Service Requirement[b]	Location Code of Serving Plant	Location Code of Serving Warehouse
001002	0	$0	0 lb	0	—	—	—
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
006009	123	890,000	600,000	153	1	005006	011007
007009	51	401,000	290,000	136	1	005006	011007
006008	37	295,000	175,000	127	2	005006	011007
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
006012	96	780,000	550,000	156	1	005006	011007
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.

[a] Grid numbers are referenced to Figure 14-2.

[b] Requirements are expressed in the number of days for delivery acceptable to customers.

The grid size is a balance between overaggregation of data and the resulting loss of accuracy in representing the data, and the needless complexity and cost associated with grid cells so fine that they fail to group like customers and, therefore, fail to benefit from averaging.

In addition, numerous geopolitical, specialized areal, and grid location codes are available. A survey of such national geocoding systems identified 33 different coding systems, 8 of which were grid and coordinate codes.[8] In addition to the grid and longitude-latitude codes, several others have been popular for logistics planning purposes. In the United States, and in other countries as well, geographic codes developed for postal delivery are popular. They frequently serve as a basis for determining the distances between points on which transport rates are established, since they are typically tied to company sales data. In the United States, the Standard Point Location Code is often used in computerized transport rating and routing systems. Standard Metropolitan Statistical Areas are frequently used in marketing analysis, which may be a reason to tie logistics analysis to them. PICADAD, a computerized point reference system used by the U.S. Bureau of the Census, Transportation Division, assists in tabulating and analyzing traffic flows.

Application

Consolidated SMC^3, a company supplying technology, tools, and data to the transport community, offers transportation rates in electronic form, as do some trucking firms such as Yellow Freight Systems and Roadway. The database and computer program, called CzarLite™, allows the user to look up a rate between any two intercity points by their five-digit zip codes. The zip code serves as a convenient location code rather than city and state names, which might otherwise be used. The rates for other common carriers, UPS, and FedEx are similarly available and may be found on the Internet.[9]

Railway freight rates in India are also available on the Internet.[10]

Because the reference numbers in these codes refer to either an area or a point, mathematical manipulation of the code numbers is possible to determine distances and travel times, and to estimate transportation rates between pairs of areas or points. This ease of data manipulation is of great advantage in facility location analysis and for approximating transportation costs.

Coding generally requires only the simplest of arithmetic operations. As can be noted in Table 14-1, such a listing is produced by sorting the data according to geographic code and by summarizing and averaging data for each data category. This type of coded data is often stored as paper reports in the form of transportation

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[8] Pamela A. Warner, *A Survey of National Geocoding Systems*, Technical Report no. DOT-TSC-74-26 (Washington, D.C. Superintendent of Documents, U.S. Government Printing Office, 1974).

[9] See www.UPS.com and www.FedEx.com, www.dhl.com.

[10] See http://www.indiastat.com and http://www.indianrail.gov.in.

rates, inventory costs, or inventory level records, to be retrieved when needed for planning.

Converting Data to Information

Data are facts without any particular purpose. Once gathered, they need to be organized, summarized, grouped, aggregated, or otherwise arranged in a manner that supports the network planning process. When this is done, data becomes information for decision making. For the network design problem, we want to look at the key information elements and their generation.

Units of Analysis

To begin network planning, the dimensions to be used in the analysis need to be decided. Common choices are some form of weight measure (lb, cwt., tons, or kg), a monetary measure (dollar, pound, or yen), a physical count (cases, units, or drums), or a volume measure (gallon, cube, or liter). A weight measure is the preferred choice by logisticians for most planning problems, since transportation rates, a dominant cost in network planning, are usually expressed in this dimension. What is commonly used by managers may be an overriding consideration, since the company's database and understanding of operations are in terms of this dimension. For example, firms primarily engaged in retail distribution view their businesses in monetary terms, whereas manufacturing firms commonly use a weight measure. Once the unit of analysis is decided, all the relevant costs for analysis need to conform to this dimension.

Product Grouping

Companies may have hundreds to thousands of individual items in their product line. This variety occurs not only because there are variations in product models and styles, but also because of the same product being packaged in many sizes (e.g., toothpaste may be offered in travel, regular, economy, and family sizes as well as in tube and pump packages). To collect all the necessary data and to conduct the analysis would be impractical for so many product items. Aggregating the items into a reasonable number of product groups is a practical approach to this problem. We seek to make this grouping so as not to substantially reduce solution accuracy.

Many of the items in any product line do not have different distribution patterns. That is, they may be warehoused at the same locations, bundled together on the same transport carrier, and be destined for the same customers. We want to exploit this by grouping those products sharing the same distribution channel, but create separate groupings for those that do not. Some common groupings would be those products that are shipped directly in bulk to customers because of their high order volume; and those that are shipped through a system of warehouses because of their low order volume requirements. Grouping products by the transport class of merchandise is another method. Of course, a company may wish to group products based on its sales groupings simply because management understands this breakdown. Whatever the method used to create product families, the aggregation of products is usually substantial. It is common to need no more than about 20 product groups for a network analysis.

Application

The Ford Motor Company purchased engines, transmissions, and wheel parts for its 13 eastern U.S. assembly plants from various vendors in Europe. The normal distribution pattern was to move these parts from vendor plants in the European hinterlands to European ports to U.S. ports to final assembly plants located in the U.S. interior. A staging warehouse was considered for location between the U.S. ports and the final assembly plants. Since the motivation for the warehouse was to save on inventories, a natural breakdown of the products was by shipment size. That is, demand was divided into less-than-container-load and full-container-load quantities, since the motivation for the warehouse was a trade-off between transportation costs and inventory-carrying costs. The favored container size was the variable used to decide product groups. A breakdown by product type was not meaningful.

Transport Rate Estimation

In network planning, transportation rates become a major problem because of the potential number of them. For a small network of only 2 product groups, 5 shipment weight breaks, 200 customers, 5 warehouses, and 2 plants, there are $2 \times 5 \times 200 \times 5 \times 2 = 20{,}000$ rates needed to represent all product flow combinations. Some form of rate estimation would speed computation and relieve the company personnel of the burden of looking up or acquiring so many rates. Such estimation must recognize the type of transportation used, whether privately owned or for hire.

Privately Owned Transport

Estimating an effective rate for privately owned transport, usually truck, requires knowledge of the operating costs and of how the vehicles are routed to their delivery or pickup points. Typically, good records are maintained of the operating costs that include driver wages and benefits, vehicle maintenance, insurance, taxes, depreciation, and overhead. Mileages are recorded from odometer readings. Therefore, a cost per mile is easily obtained.

Example

The Grand Island Biological Company produces and distributes culture media for growing and identifying certain bacteria useful in medical research. Customers primarily are the large medical research complexes located in such areas as New York and Washington, D.C. To evaluate private trucking (small refrigerated vans were used for delivery of these temperature-sensitive products), the company provided the following data about their trucking operations on a weekly basis in the Washington, D.C. area:

Data Category	Fact	Weekly Cost
Weekly mileage	2700 miles	
Weekly hours on duty	66 hrs./wk.	
Trips per week	3 trips/wk.	
Driver wages	$12.00/hr.	$ 792.00
Benefits	18.75% of wages	148.50
Fuel cost @ 10 mpg	$1.10/gal	297.00
Truck depreciation	$316.50/wk.	316.50
Maintenance	$45.00/wk.	45.00
Insurance	$51.00/wk.	51.00
Tolls, food, and lodging	$97.50/trip	292.50
Contingency	$30.00/trip	90.00
Total		$2,032.50

The trucking cost can then be calculated as $2,032.50/2700 mi. = $0.75 per mile.

It is more difficult to estimate the effective rate between origin and destination because the vehicle does not travel a direct route between the two. Rather, more than one stop is frequently made before returning to the depot. Suppose that there are five stops on a typical route and the average out-and-back driving distance is 300 miles, as might be determined by averaging a number of typical route patterns [see Figure 14-3a]. In this example, stem driving distance is a total of 200 miles and interstop driving distance is a total of 100 miles. If the average actual transport rate is taken as $1.30 per mile, the total actual transport cost for the five stops would be $1.30/mile × 300 miles = $390.00. Since, for planning purposes, we often estimate the distance to a customer in one direction only [see Figure 14-3b], the effective distance is 100 + 100 + 150 + 110 + 100 = 560 miles. The effective rate per direct mile would be $390.00/560 = $ 0.696 per mile. Hence, in planning, we calculate the straight-line distance to a customer and multiply it by the effective rate of $0.696/mile to find the transport cost to that customer.

For-Hire Transport

The process to estimate transport rates for for-hire transport is significantly different from the process just described for privately controlled transport. A characteristic of class rates for truck and rail, and rates for UPS and FedEx as well as other small-shipment carriers, is that the rates are reasonably linear with distance, a characteristic that we can use to advantage. This allows us to build a transport rate estimating curve that is based on distance traveled from a shipment origin point, like that shown in Figure 14-4. For a range of distances from a local delivery area of about 30 to 50 miles from the origin to the area of rate blanketing of about 1,000 to 1,500 miles from the origin, the rates are usually very linear with distance, typically having a coefficient of determination of 90 percent or higher. This has been observed for the United States as well as for other countries.

Figure 14-3
Actual Versus Equivalent Driving Patterns for Privately Operated Vehicles

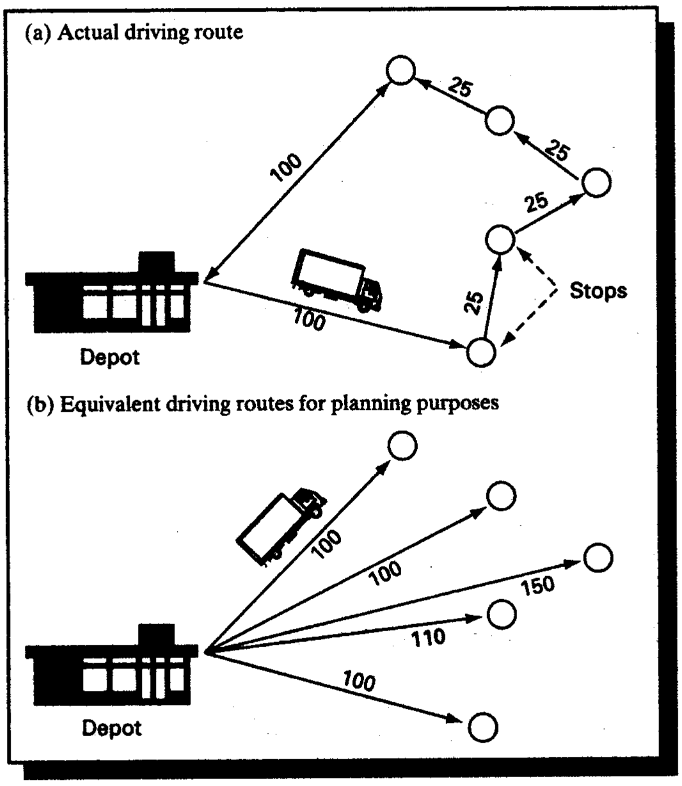
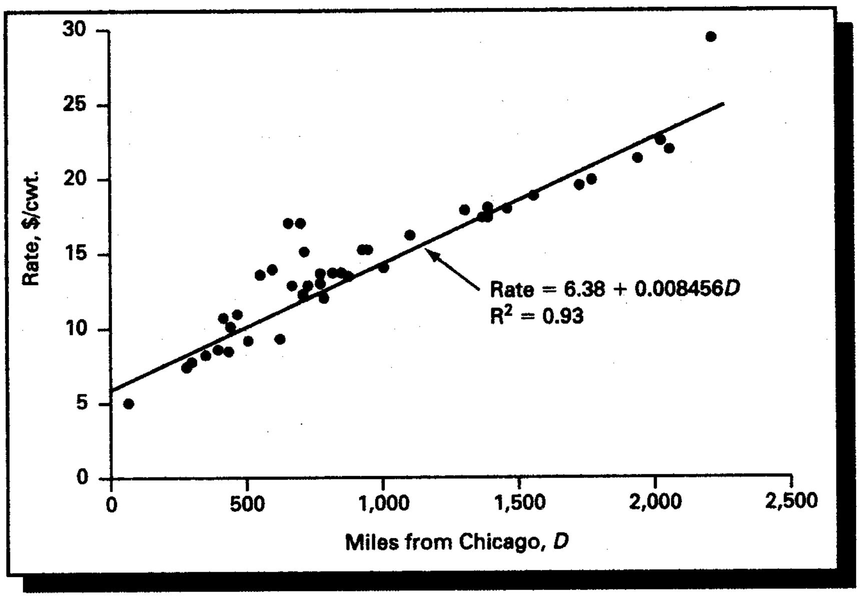


Figure 14-4
Transport Rate Estimating Curve for Selected Distances from Chicago



The process for constructing a transport rate estimating curve involves sampling rates at varying distances radiating from an origin point, say, Chicago. A sample size of between 30 and 50 points is usually adequate. The rates may be found in tariffs or other rate quotations. In the case of Figure 14-4, the rates were taken from the Roadway Express rates without discounts or other service charges, as found on the Internet.[11] Since rates are quoted between postal codes, the distances may be found through map scaling or from tabulated distances in such publications as the Rand McNally Road Atlas,[12] Bartholomew Road Atlas Europe,[13] or from the mapping services on the Internet.[14] Commercial databases in electronic form are available. Distances also may be calculated from geographic coordinates, as discussed later in this chapter.

When a transport rate estimating curve does not produce a satisfactory degree of accuracy, specific rates may be used entirely or selectively in conjunction with a transport rate estimating curve. This may happen where rates are quoted on individual shipments such as for high-volume movements between specific points. Contract, commodity, and selectively discounted class rates may not show enough of a generalized relationship with distance to form a reasonable rate estimating curve.

Order and Shipment Profiles

Network design can be very sensitive to order size and the resulting shipment size. For example, if all customers had their orders shipped to them in full truckload quantities, there would be little economic incentive for warehousing, outside of having stock near customers for service reasons. On the other hand, very small customer orders frequently require extensive warehousing of stocks. However, a firm usually has many customers that it ships to in a variety of order weights. In Figure 14-5, the chemical company represented had divided its market into large and small accounts. Large accounts were generally managed by a direct sales force, whereas the small accounts were handled by telephone through a telemarketing program. This histogram shows the percentage of the shipments for each account type within a standard weight-break cell. Data for such distributions are generally available from shipping document samples or from the sales database.

The value of the shipment profile is to produce accurate estimates of transport rates. Between the same origin and destination points, there can be a substantially different rate, depending on the shipment weight. Therefore, transport rate estimating curves need to be developed for each standard weight break. Then, each rate curve can be weighted by the corresponding percentage of shipments in the weight break. One resulting transport rate curve can then represent a wide range of shipment sizes or a variety of transport modes, as the shipping profile may represent different modes as well as weight breaks.

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[11] www.Roadway.com.

[12] *Rand McNally 2002 Road Atlas* (Skokie, IL: Rand McNally and Company, 2002).

[13] *Bartholomew Road Atlas Europe* (Edinburgh, Scotland: John Bartholomew & Son, Ltd., 1985).

[14] For example, see www.MapQuest.com or www.RandMcNally.com.

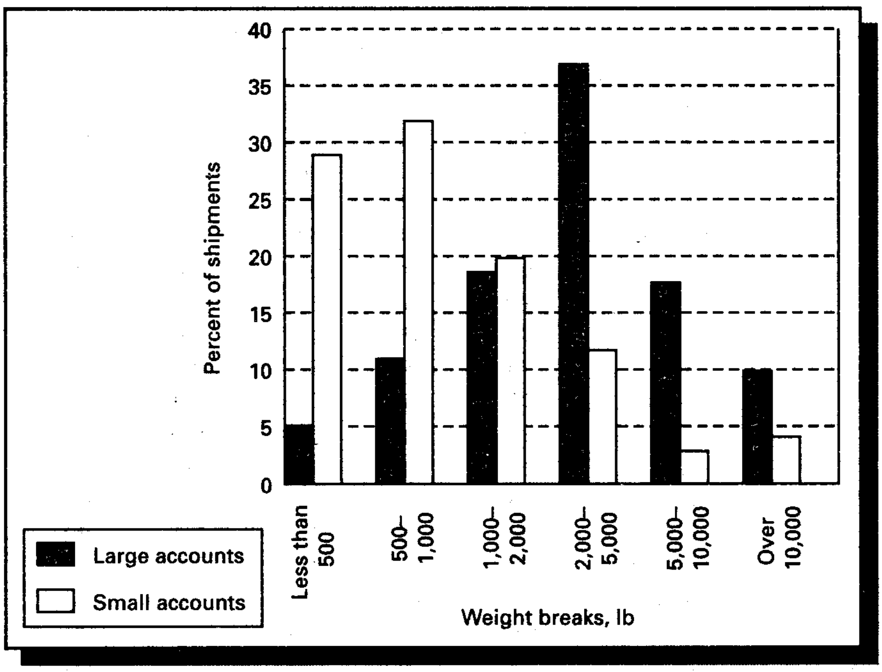

Figure 14-5 A Shipment Profile for Large and Small Accounts of a Chemical Company

Sales Aggregation

Customers for any firm's products or services are typically dispersed throughout a country, yet they are often concentrated in specific areas, usually population centers. From a network-planning viewpoint, it is not necessary to treat each customer separately. The product, or service, sales that thousands of customers generate can be geographically grouped into a limited number of geographic clusters without any significant loss in cost-estimating accuracy.

Sales clustering can affect the accuracy of estimating transportation costs to customers. With clustering, transport costs, rather than being computed to each customer location, are computed to the cluster center. Some error through using the average rather than actual distance will be introduced. This potential inaccuracy can be minimized if an adequate number of clusters are created, and these clusters are kept small around the greatest concentrations of sales. Based on research that determines the transportation cost error of assuming that shipments are made to the center of a customer cluster rather than to each customer, the appropriate number of clusters can be determined. Table 14-2 shows various cluster sizes depending on the number of facilities in a network and the allowable transport costing error.

Once the proper number of clusters is known, customer data can be aggregated into these clusters. Since sales are usually given by customer address, which includes zip code, it is common to group by zip code. Grouping zip codes by their proximity

Maximum Allowed Error	Largest Cluster Size[a]	Approximate Number of Source Points in Network					
		1	5	10	25	50	100
0.5%	0.5%	200[c]	325	350	500	650	750
	0.8%	150	150	175	375	450	650
	2.0%	75	100	300	450	600	650
	5.0%	75	150	250	500	600	750
	Unlimited[b]	50	350	400	500	700	750
1.0%	0.5%	200[c]	200[c]	200[c]	200[c]	250	500
	0.8%	200[c]	150	150	175	350	500
	2.0%	75	75	175	300	500	600
	5.0%	75	100	225	400	500	600
	Unlimited[b]	25	200	250	400	500	600
2.0%	0.5%	200[c]	200[c]	200[c]	200[c]	200[c]	350
	0.8%	150	150	150	150	250	450
	2.0%	75	75	100	250	350	500
	5.0%	75	75	175	300	450	500
	Unlimited[b]	25	75	175	300	450	500
5.0%	0.5%	200[c]	200[c]	200[c]	200[c]	200[c]	200[c]
	0.8%	150	150	150	150	150	300
	2.0%	75	75	75	100	225	300
	5.0%	75	75	75	175	275	350
	Unlimited[b]	25	50	75	200	275	350
10.0%	0.5%	200[c]	200[c]	200[c]	200[c]	200[c]	200[c]
	0.8%	150	150	150	150	150	150
	2.0%	75	75	75	75	125	175
	5.0%	75	75	75	75	150	200
	Unlimited[b]	25	50	75	100	175	225

[a] Largest cluster size among all clusters as a percentage of total demand.

[b] Cluster size is not specifically limited, but is approximately 7 percent of total demand.

[c] Mathematically the minimum number of clusters.

Source: Ronald H. Ballou, "Measuring Transport Costing Error in Customer Aggregation for Facility Location," *Transportation Journal*, Vol. 33, No. 3 (1994), pp. 49–59.

Table 14-2 Minimum Acceptable Number of Clusters for the Maximum Allowed Transport Costing Error and for Various Numbers of Network Source Points and Largest Customer Cluster Sizes

to each other gives a low transport costing error. Each cluster center can be identified using a geocode such as latitude and longitude. An example table of cluster centers, their geographical locations, and the zip sectional centers associated with each cluster can be formed, as shown in Table 14-3. Similar cluster tables can be generated for other parts of the world, using whatever postal code may be in effect in that particular region.

No.	Longitude[a]	Latitude[a]	Cluster Center City Name	Center Zip Code[b]	Zip Codes Represented[b]
1	73.25	42.45	Pittsfield, MA	012	012
2	71.81	42.27	Worcester, MA	016	015–016
3	71.08	42.31	Boston, MA	021	014, 017–024
4	71.43	41.82	Providence, RI	029	025–029
5	71.46	42.98	Manchester, NH	031	030–034
6	72.02	44.42	St. Johnsbury, VT	035	035, 058
7	70.97	43.31	Rochester, NH	038	038–039
8	70.28	43.67	Portland, ME	041	040–041, 045, 048
9	69.77	44.32	Augusta, ME	043	042–043, 049
10	68.75	44.82	Bangor, ME	044	044, 046
11	68.00	46.70	Presque Isle, ME	047	047
12	73.22	44.84	Burlington, VT	054	054, 056
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
180	117.05	32.62	San Diego, CA	921	920–921
181	119.00	35.56	Bakersfield, CA	933	932–934
182	119.78	36.76	Fresno, CA	937	936–937
183	122.21	37.78	Oakland, CA	946	939–954
184	124.07	40.87	Arcata, CA	955	955,960
185	121.46	38.55	Sacramento, CA	958	956–959
186	121.67	45.46	Portland, OR	972	970–974, 977, 986
187	121.75	42.22	Klamath Falls, OR	976	975–976
188	118.80	45.66	Pendleton, OR	978	978
189	122.33	47.63	Seattle, WA	981	980–985
190	120.47	46.60	Yakima, WA	989	988–989
191	117.41	47.67	Spokane, WA	992	835, 838, 990–992, 994
192	118.33	46.06	Walla Walla, WA	993	993

[a] Longitude and latitude coordinates in decimal degrees.

[b] Zip sectional center code.

Table 14-3 Partial Listing of a Geographic Clustering Scheme for the United States. Using 192 Clusters, Three-Digit Zip Sectional Centers, and Longitude-Latitude Coordinates

Mileage Estimates

The geographical nature of much of the network planning task requires logisticians to obtain distances. Distances are needed to estimate transport costs between origin and destination points, and they are frequently used as a substitute for time. For example, all customers may be required to be located within 300 miles of a warehouse, meaning that one-day delivery service can be achieved at that distance. As previously noted, distance data can be found in a number of commercial tables and road atlases in either printed or computerized form.[15] For other situations (e.g., planning truck routes through city streets), a handheld wheel-on-a-handle measuring device, available in many office supply stores, can be rolled over a map to obtain precise distances that a vehicle might actually travel. However, it is frequently more efficient, but not always as accurate, to simply compute distances from coordinate points.

When a simple, linear grid system is used, as previously shown in Figure 14-2, straight-line distances can be computed from the coordinates by means of the Pythagorean theorem. That is, if points A and B have given coordinate values, the straight-line distance between them can be determined by

$$D_{A-B} = K\sqrt{(X_B - X_A)^2 + (Y_B - Y_A)^2} \tag{14-1}$$

where

D_{A-B} = distance between points A and B
X_A, Y_A = coordinates for point A
X_B, Y_B = coordinates for point B
K = scale factor to convert the coordinate measure to a distance measure.

Example

Suppose that we want to estimate the distance between a plant at Madrid, Spain, and the warehouse at Milan, Italy, as shown in Figure 14-2. Madrid has coordinates $X_A = 5$, $Y_A = 6$ and Milan has coordinates $X_B = 11$, $Y_B = 7.5$. The map-scaling factor, or distance between successive coordinate numbers, is 194 kilometers. The computed straight-line distance is

$$\begin{aligned} D_{A-B} &= 194\sqrt{(11-5)^2 + (7.5-6)^2} \\ &= 1200\,\text{km} \end{aligned}$$

The road distance from a road atlas is 1724 km. The road distance exceeds the computed distance because of the circuity with which a vehicle must normally travel.

If rectangular distances are desired to conform better to the rectangular layout of roads, especially in cities, a generalized distance formula can be used:

$$D_{A-B} = b_0 + b_1[|X_A - X_B| + |Y_A - Y_B|] + b_2\sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2} \tag{14-2}$$

where b_0, b_1, and b_2 are found by fitting the equation to active versus straight-line distances.[16]

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[15] Many of the commercial computer products for mileage determination can be found in Accenture's annual guide to logistics software available through the Council of Logistics Management at www.CLM1.org.

[16] Jack Brimley and Robert Love, "A New Distance Function for Modeling Travel Distances in a Transportation Network," *Transportation Science*, Vol. 26, No. 2 (1992), pp. 129–137.

Due to distortions caused by various mapping techniques for projecting a globe onto a plane, the simple grid overlay technique may produce computational errors that vary, depending on the map projection method and where on the map the distances are computed. A more reliable technique is to use longitude-latitude coordinates and the great circle (spherical trigonometry) distance formula. Not only does the formula avoid mapping distortions, it also accounts for the curvature of the earth. The great circle formula is

$$\begin{aligned} D_{A-B} = {} & 3959\{\arccos[\sin(\mathrm{LAT}_A) \times \sin(\mathrm{LAT}_B) \\ & + \cos(\mathrm{LAT}_A) \times \cos(\mathrm{LAT}_B) \times \cos|\mathrm{LONG}_B - \mathrm{LONG}_A|]\} \end{aligned} \qquad \textbf{(14-3)}$$

where

D_{A-B} = great circle distance between points A and B (statute miles)
LAT_A = latitude of point A (radians)[17]
LONG_A = longitude of point A (radians)
LAT_B = latitude of point B (radians)
LONG_B = longitude of point B (radians)

Although this formula appears to be rather intimidating, it can be easily computer programmed,[18] and its advantages can outweigh this disadvantage. Some of these advantages are

- Latitude and longitude coordinates can be used around the world.
- The coordinates are available from a wide variety of sources, including road maps, navigational maps, encyclopedias, government publications, and commercial services.
- The coordinate system is generally understood.
- Good accuracy is achieved.

Therefore, the great circle method of distance computation is frequently the method of choice in computer programs for logistics planning. However, to preserve computational accuracy, the two points in the formula should be within the same hemisphere.

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[17] Radians are computed from degrees by dividing them by 57.3, i.e., $180/\pi$.

[18] A small program in the BASIC programming language to compute the great circle distance from coordinates in degrees would be

```
100  C = 57.3
110  A = SIN(LATA/C) * SIN(LATB/C) + COS(LATA/C) * COS(LATB/C)
         * COS(ABS(LONGB - LONGA)/C)
120  D = 3959 * ATN(SQR(1 - A^2)/A)
```

where

D = distance in statue miles from the first to the second point
C = a constant to convert degrees to radians
LATA = latitude of the first point in degrees
LONGA = longitude of the first point in degrees
LATB = latitude of the second point in degrees
LONGB = longitude of the second point in degrees

Example

Continue the previous example by computing the straight-line distance from Madrid to Milan, but use the great circle distance formula. The coordinates for Madrid are $\text{LONG}_A = 3.41°\text{W}$, $\text{LAT}_A = 40.24°\text{N}$ and for Milan the coordinates are $\text{LONG}_B = 9.12°\text{E}$, $\text{LAT}_B = 45.28°\text{N}$. Dividing each of these coordinates by 57.3 converts them to radians. Hence, $\text{LONG}_A = 0.0595$, $\text{LAT}_A = 0.7023$, $\text{LONG}_B = -0.1592$, $\text{LAT}_B = 0.7902$. Note that LONG_B is negative since it is east of the Greenwich line and LONG_A is positive being west of that line. Putting this information in Equation (14-3), we have

$$
\begin{aligned}
D_{A-B} &= 3959\{\arccos[\sin(0.7023) \times \sin(0.7902) \\
&\quad + \cos(0.7023) \times \cos(0.7902) \times \cos|-0.1592 - 0.0595|]\} \\
&= 724 \text{ miles}
\end{aligned}
$$

Since there are 1.61 kilometers per mile, $D_{A-B} = 724 \times 1.61 = 1166$ kilometers. (*Note*: Arccos, sin, and cos values are found from trigonometric tables.)

Computed distances will always understate the actual distance between two points. Vehicles do not travel in a straight line. Rather, they move through a network of road, rail, or navigational routes, balancing distance and time to traverse the network. Because of this, computed distances are adjusted using a circuity factor, or multiplier. When the grid is a simple, linear type and Equation (14-1) is used, the circuity factor is approximately 1.21 for roads and 1.24 for railroads in well-developed networks. When using latitude-longitude coordinates in the great circle formula to compute distance [Equation (14-3)], circuity factors for various regions of the world, as given in Table 14-4, are good starting values. A precise circuity factor for any particular region can be determined simply by taking a sample of distances between selected points and averaging the ratio of actual-to-computed distances.

In addition to mileage estimates, time estimates are sometimes needed to reflect customer service in the network. A common practice is first to estimate distances and then to convert them to time estimates by dividing distance by travel speed. However, some research has been done to estimate transit times for intercity and intracity networks. Camp and DeHayes developed regression equations for estimating intercity transit times using a grid system.[19] Ratliff and Zhang estimate speed and time for regions the size of cities.[20]

Facility Costs

Costs related to a facility such as a warehouse can be represented in terms of (1) fixed costs; (2) storage costs; and (3) handling costs. Fixed costs are those that do not change with the activity level of the facility. Real estate taxes, rent, supervision, and

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[19] Robert Camp and Daniel DeHayes, "A Computer-based Method for Predicting Transit Time Parameters Using Grid Systems," *Decision Sciences*, Vol. 5 (1974), pp. 339–346.

[20] H. Donald Ratliff and Xinglong Zhang, "Estimating Traveling Time/Speed," *Journal of Business Logistics*, Vol. 20, No. 2 (1999), pp. 121–139.

COUNTRY	NUMBER OF POINTS	AVERAGE CIRCUITY FACTOR	STANDARD DEVIATION
Argentina	66	1.22	0.15
Australia	77	1.28	0.17
Byelorussia	21	1.12	0.05
Brazil	120	1.23	0.11
Canada	49	1.30	0.10
China	66	1.33	0.34
Egypt	21	2.10	1.96
Europe	199	1.46	0.58
England	37	1.40	0.66
France	9	1.65	0.46
Germany	31	1.32	0.95
Italy	11	1.18	0.10
Spain	61	1.58	0.80
Hungary	36	1.35	0.25
India	105	1.31	0.21
Indonesia	16	1.43	0.34
Japan	36	1.41	0.15
Mexico	49	1.46	0.43
New Zealand	4	2.05	1.63
Poland	45	1.21	0.09
Russia	78	1.37	0.26
Saudi Arabia	21	1.34	0.19
South Africa	91	1.23	0.12
Thailand	28	1.42	0.44
Turkey	28	1.36	0.34
Ukraine	36	1.29	0.12
United States[a]	299	1.20	0.17
Alaska	55	1.79	0.87
US East[b]	143	1.20	0.16
US West[c]	156	1.21	0.17

[a] Excluding Alaska and Hawaii
[b] East of the Mississippi River
[c] West of the Mississippi River

Source: Ronald H. Ballou, Handoko Rahardja, and Noriaki Sakai "Selected Country Circuity Factors for Road Travel Distance Estimation," *Transportation Research*, Part A, Vol. 36 (2002), pp. 843–848.

Table 14-4 Circuity Factors for Selected Countries (and Areas of the United States) depreciation are examples of fixed costs. However, we should recognize that all costs are variable at some activity level. Careful consideration must be given as to whether cost is likely to change over a reasonable activity range that may be applied to a facility when classifying a cost as fixed.

Storage costs are those that vary with the amount of stock stored in the facility. That is, if a particular cost will increase or decrease with the level of inventory maintained in the facility, then the cost will be classified as a storage cost. Typical costs here might be some utilities, personal property taxes, capital tied up in inventory, and insurance on inventory value.

Handling costs vary with the facility throughput. Typical examples are labor costs to store and retrieve items, some utility costs, and variable handling equipment costs.

Private or leased warehousing costs are tracked through a firm's accounting system. Reports are periodically issued as a list of accounts, giving costs and their associated descriptions. Judgment must be used to classify these data as annualized fixed, storage, and handling costs useful for network planning.

Example

A major oil company's warehouse stocks tires, batteries, and accessories that are sold through gasoline retail outlets. An accounting report of expenses associated with the operation of the warehouse for one year is shown in Table 14-5. This author has made judgments as to how the expenses might be allocated to fixed, storage, and handling cost categories as would be needed for network planning. See if you would allocate them any differently.

When public warehouses are involved, storage and handling rates are easily obtained. The service is for hire and can be purchased generally in direct proportion to the amount needed. Rates for storage ($/cwt./month) and handling ($/cwt.) appear on the public warehouse contract. No fixed costs apply since this is a for-hire service. However, there may be vendor discounts offered based on the length of contract and the projected volume.

Costs for plants and vendors are also easily found. The variable costs for the plant output by product are usually obtained from the accounting standard costs for production. For purchased goods, vendor costs are the prices quoted to the buyer.

Facility Capacities

Strict capacity limitations on plants, warehouses, and vendors can have a substantial impact on network configuration. Yet capacities, in practice, are not absolute, rigid values. While there may be a most efficient throughput at which a facility operates, working overtime, working additional shifts, storing product in the aisles, and securing additional equipment or space on a temporary basis are just a few of the ways that capacity may be expanded. Although these come at an increased cost, care should always be taken to not view capacities as too rigid a constraint.

ACCOUNT DESCRIPTION	TOTAL EXPENSE	ANNUAL FIXED COST	STORAGE COST	HANDLING COST
Salaries and wages[a]	$347,440	$36,500	$	$310,940
Overtime pay	40,351			40,351
Part-time temporary workers	23,551			23,551
FICA	27,747	2,915		24,832
Unemployment pay	4,437	466		3,971
Travel expense	5,716	5,716		
Meals for overtime	844			844
Benefit plan expense	19,619	2,061		17,558
Group insurance	14,860	1,561		13,299
Janitor expense—material	5,481	5,481		
Snow and rubbish removal	2,521	2,521		
Building and grounds maintenance	19,780	19,780		
Fire protection	2,032	2,032		
Landscaping	3,855	3,855		
Blacktop[b]	15,621	15,621		
Unsalable merchandise	4,995		4,995	
Security	583	583		
Office supplies and forms	38,697			38,697
Postage	518			518
General warehouse supplies	64,338			64,338
Electric	39,332	39,332		
Heat	28,974	28,974		
Telephone	8,750	8,750		
Books, subscriptions	1,017	1,017		
Membership dues and expense	3,993	3,993		
Taxes—real estate	43,570	43,570		
Taxes—personal property	35,354		35,354	
Truck expense	12,961			12,961
Materials handling equipment expense	29,042			29,042
Totals		$224,728	$40,349	$580,902

[a] Includes warehouse manager.

[b] Amortized over 10 years.

Table 14-5 Annual Warehouse Expenses Allocated to Fixed, Storage, and Handling Cost Categories

Inventory-Throughput Relationships

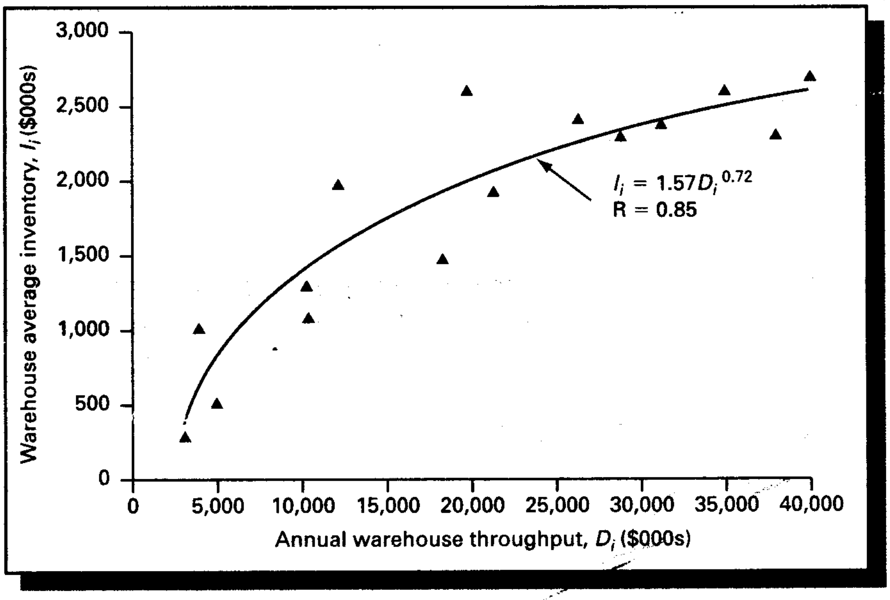
When planning involves the location of warehouses, it is usually necessary to estimate how inventory levels throughout the network will be affected as warehouse number, location, and size change. Recall from Chapter 9 on inventory, there are two forces acting on inventory levels—regular stock and safety stock. As the number of facilities is reduced in a network, the inventory levels will generally decline. Recall that the square-root law predicts the reduction in regular stock; it fails to estimate safety stock effects. Using the inventory throughput will help to estimate both effects.

Because the location problem is one of allocating demand among warehouses, we would like to be able to project the amount of inventory in a warehouse from the demand, or throughput, assigned to it. One way to find the inventory-throughput relationship is to generate it from the company's own inventory policy. That is, an inventory turnover ratio of eight turns per year may be the goal. Since the turnover ratio is annual sales to average inventory, the relationship is defined. However, this is an expression of what management intends and not what actually occurs. It simply may be the best relationship that we have if no other information is available.

Perhaps a better way to find the inventory-throughput relationship is to observe how management controls inventories. A common report for most firms is the stock status report that gives monthly inventory levels and shipments for each warehouse in the network. By averaging the inventory levels for each warehouse and summing the shipments, a data point on a graph can be found, as shown in Figure 14-6. Plotting similar data for all warehouses and plant locations that act as warehouses serving their local territories completes the data profile. We then fit the best mathematical equation to the data that can be found. From this equation, knowing the annual demand assigned to an existing or new warehouse, we can estimate, on the average, the amount of inventory that should be in a particular warehouse.

When (1) there are few warehouses in the existing network from which to generate a reasonable data profile; (2) the execution of the inventory policy is so varied between warehouses that an aggregate relationship cannot be accurately established;

Figure 14-6 An Inventory-Throughput Curve for a Producer of Industrial Cleaning Compounds



or (3) the inventory policy is to be changed, it then may be necessary to estimate the average inventory level from the inventory policies for individual product items. This can be accomplished by simulating the action of demand on individual items in a warehouse and summing the results to an aggregate inventory level for all items. How a company controls each of the items is reflected in the total inventory levels. By dividing demand among varying numbers of possible warehouses, simulated data can be generated as shown in Figure 14-6.[21]

Future Demand Estimation

It makes little sense to plan the network based on past or current demand data when the results of the planning are not likely to be implemented immediately. Therefore, we seek some future year for design purposes. Medium- to long-range forecasting methods may be useful here. As an alternative, many firms produce a five-year forecast for general planning purposes. This can be useful information for network planning as well.

Other Factors and Strictures

After the basic economic data has been gathered, information will still be needed on various restrictions that may affect network design. Bender outlines these as follows:

- Financial limitations, such as maximum allowable investment in new facilities
- Legal and political constraints determining, for example, the need to avoid certain areas in evaluating potential sites
- Manpower limitations, such as the number and quality of personnel available to support new strategies
- Deadlines to be met
- Facilities that must be kept operating
- Contractual conditions, both existing and anticipated[22]

Missing Information

One of the more perplexing problems in network planning is not having all the necessary data needed to carry out the analysis. This frequently occurs when the analysis involves facilities not currently operated by the company. For these facilities, no definitive costs are available concerning their operation. They must be either estimated or acquired externally. An estimating approach is to borrow from existing data, either from currently operated facilities in the same proximity of the potential facility, or from facilities having the same general characteristics. Transport rate curves may be duplicated at new locations or new samples of rates may be drawn from around these new origin points. Estimates of average inventory levels are taken from the average inventory-throughput curve.

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[21] For an in-depth discussion of aggregate inventory-throughput relationship development, see Ronald H. Ballou, "Estimating and Auditing Aggregate Inventory Levels at Multiple Stocking Points," *Journal of Operations Management*, Vol. 1, No. 3 (1981), pp. 143–153; and Ronald H. Ballou, "Evaluating Inventory Management Performance Using a Turnover Curve," *International Journal of Physical Distribution and Logistics Management*, Vol. 30, No. 1 (2000), pp. 72–85.

[22] Paul S. Bender, "Logistic System Design," in James F. Robeson and Robert G. House (eds.), *The Distribution Handbook* (New York: Free Press, 1985), p. 173.

Information not available within the company may sometimes be found outside it. Economic data such as labor rates, leasing rates, taxes, and construction costs may be found from regional labor surveys periodically conducted by the Department of Labor. The various chambers of commerce conduct local economic surveys that provide data useful for developing warehouse costs. Roadway Pilot, Yellow Freight, and other trucking companies offer free disks, or Internet access to them, of their transportation rates between hundreds of intercity origin and destination points around the United States. Several vendors offer transport rates for sale, such as the SMC^3 Corporation.[23] Public warehousemen will quote rates. Although data from these sources do not represent "hard negotiation" on the part of the firm, they do provide ways of filling in some missing data.

THE TOOLS FOR ANALYSIS

When the appropriate information has been developed for network planning, analysis to find the best design can begin. For this problem type, the process of searching for the best designs is complex and is usually assisted through the use of mathematical and computer modeling. Consider some of the choices.

Choices for Modeling

Although there are numerous individual models that can be used for analysis, models may be classified in just a few categories, namely, (1) chart, compass, and ruler techniques; (2) simulation models; (3) heuristic models; (4) optimization models; and (5) expert system models. Some of these models were discussed in Chapter 13.

Chart, Compass, and Ruler Techniques

This is a general label referring to a wide variety of intuitive techniques aided by a relatively low level of mathematical analysis. However, the results need not be of low quality. Insight, experience, and a good understanding of network design allow an individual to generate satisfactory designs. Subjective factors, exceptions, costs, and constraints, many of which cannot be represented by the most elaborate mathematical model, can be taken into account. This enriches the analysis and is likely to lead to designs that can be directly implemented.

Methods used to support this type of analysis are likely to seem rudimentary in today's computerized world. Statistical charting, mapping techniques, and spreadsheet comparisons are just a few of the techniques that might be employed.

Application

When labor threatened to unionize at a brake manufacturing plant, its owner sought to move operations to another location. The plant was located in a Midwestern state where labor unions were traditionally strong. The plant's owner

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[23] See www.SMC3.com.

wanted the new location to be in a right-to-work state. Given the limited number of locations that this stricture implied for a single new facility, each location was easily cost-analyzed with the use of a handheld calculator. Once the general region of the country for location was identified, the final site was selected by comparing many subjective factors, such as quality of local education, community attitudes about the operation, and the availability of transportation and utilities. Specific costs associated with the site were also considered, such as real estate and local taxes, utility rates, and rents.

Simulation Models

Simulation models are represented by two types: (1) deterministic simulation and (2) stochastic, or Monte Carlo, simulation. Deterministic simulators are essentially cost calculators, where the values of structural variables (e.g., product flows in a network) are given to the model and it in turn calculates the costs, services statistics, and other relevant information. On the other hand, stochastic simulators attempt to mimic actual events (e.g., order patterns, transport delivery times, and inventory levels over time in a supply channel) using probability distributions to represent the uncertainty in the time of events and the level of the event variables. Deterministic simulations are typically used to evaluate a company's current network design so that a "base case" can be established against which optimized network designs may be compared. Stochastic simulations are used to show the performance results of inventory control methods, transport service selection, customer service policies, and so on. Stochastic simulations deal effectively with the *time* dimension of supply chain planning whereas deterministic simulators are used in conjunction with spatial network design.

Simulating the network ordinarily involves replicating the cost structures, constraints, and other factors that represent the network in a reasonable manner. This replication is usually done by means of mathematical relationships, which are often stochastic in nature. Then, the simulation procedure typically is

> . . . nothing more or less than the technique of performing sampling experiments on the model of the system.[24]

That is, a particular network configuration is presented to the simulation model that then provides the costs and other data relevant to the operation of the system design. Repeating the experiment many times over with the same design and with different designs generates statistics that are useful in making comparisons among the design choices. Due to the complexity of the model relationships and the amount of information handled in simulations, they are ordinarily conducted on a computer. Manipulating the simulation model rather than the real system is done as a matter of convenience.

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[24] Frederick S. Hiller and Gerald J. Lieberman, *Introduction to Operations Research*, 3rd ed. (San Francisco: Holden-Day, 1980), p. 643.

Simulations have been used to deal with about every planning problem in logistics. Some years ago, Shycon used a (deterministic) simulation to help locate warehouses.[25] Andersen Consulting (now Accenture) has used the technique (stochastic simulation) to analyze the flow of product through multiple echelons of facility locations with the purpose of answering questions relating to inventory levels, production output, and timing of flows in the supply-distribution channel.[26] Powers and Closs investigated the effects of trade incentives on logistical performance using simulation.[27] Many more examples exist.

Simulations are, for the most part, tailor-made to the particular problem being analyzed. Although a few simulators exist that specifically handle logistical problems, such as LREPS,[28] PIPELINEMANAGER,[29] LSD,[30] and LOCATE,[31] many other simulators may be created with the aid of general simulation languages. These include SIMSCRIPT, GPSS, SIMULA, DYNAMO, SIMFACTORY, and SLAM. A number of these languages now include a graphics feature whereby the action of product flows and stocking levels can be animated in simulated time on a video screen for easier interpretation of the results.

Stochastic simulation is the method of choice when substantial detail in a complex problem description is essential, when there are stochastic elements in the problem, and when finding the mathematically optimum solution is not critical. Practitioners rank simulation as the second most frequently used quantitative technique for analysis, ranking it only behind statistics.[32]

A stochastic simulator called SCSIM is available as part of the LOGWARE package. It replicates a multi-echelon supply channel and allows the testing of various forecasting methods, inventory policies, prices, transportation delivery times, production lot sizes and processing times, order processing times, and item fill rates. Results include projected revenue, various logistics and production costs by echelon, customer service statistics, inventory levels, back orders, and fill rates. More will be said about this simulator later in this chapter.

Ennore Foundries Limited (EFL), the largest automotive jobbing foundry in India, is to set up a workshop with computer simulation facility to produce patterns and tools. The workshop will be of global standards and will serve the three foundries of the company. It will reduce time delays in developing castings for

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[25] H. N. Shycon and R. B. Maffei, "Simulation-Tool for Better Distribution," *Harvard Business Review*, Vol. 38 (November–December 1960), pp. 65–75.

[26] PIPELINEMANAGER™, a proprietary computer simulation software package of Accenture, Chicago, Illinois.

[27] Thomas L. Powers and David J. Closs, "An Examination of the Effects of Trade Incentives on Logistical Performance in a Consumer Products Distribution Channel," *Journal of Business Logistics*, Vol. 8, No. 2 (1987), pp. 1–28.

[28] Donald J. Bowersox, O. K. Helferich, P. Gilmour, F. W. Morgan, Jr., E. J. Marien, G. L. Lawrence, and R. T. Rogers, *Dynamic Simulation of Physical Distribution Systems* (East Lansing, MI: Division of Research, Graduate School of Business Administration, Michigan State University, 1972).

[29] A simulator of logistics channel product flows developed by Andersen Consulting, a division of Arthur Andersen and Company.

[30] David Ronen, "LSD—Logistic System Design Simulation Model," *Proceedings of the Eighteenth Annual Transportation and Logistics Educators Conference* (Boston: October 9, 1988), pp. 35–47.

[31] A simulator for facility location developed by CSC Consulting.

[32] John L. Harpell, Michael S. Lane, and Ali H. Mansour, "Operations Research in Practice: A Longitudinal Study," *Interfaces*, Vol.19, No. 3 (May–June 1989), 65–74.

customers. EFL also plans to set up casting machining facilities to meet specific needs of its customers.[33]

Heuristic Models

Heuristic models are something of a blend of the realism in model definition that can be realized by simulation models and the search for optimum solutions achieved by optimization models. They generally achieve a broad problem definition, but do not guarantee optimum problem solutions. The models are built around the concept of the heuristic, which Hinkle and Kuehn define as

> A short cut process of reasoning . . . that searches for a satisfactory, rather than an optimal, solution. The heuristic, which reduces the time spent in the search for the solution of a problem, comprises a rule or a computational procedure, which restricts the number of alternative solutions to a problem, based upon the analogous human trial-and-error process of reaching acceptable solutions to problems for which optimizing algorithms are not available.[34]

Heuristic modeling is a practical approach to some of logistics' most difficult problems. Heuristics are useful where the desire is for the model to search for a best solution, but too much might need to be compromised to solve the problem by optimizing methods. We often use heuristics in planning, where they may appear as principles or concepts. Examples of heuristic rules might be

- The most likely sites for warehouses are those that are in or around the centers of greatest demand.
- Customers that should be supplied directly from source points and not through a warehousing system are those that can purchase in full-vehicle-load quantities.
- A product should be warehoused if the differential in transportation costs between inbound and outbound movement justifies the cost of warehousing.
- Items in a product line that are best managed by just-in-time procedures, rather than statistical inventory control, are those that show the least variability in their demand and lead time patterns.
- The next warehouse to add to a distribution system is the one that shows the greatest cost savings.
- The most expensive customers from a distribution standpoint are those that purchase in small quantities and are located at the end of the transportation lanes.
- Economical transportation loads are built by consolidating small-volume loads into full-vehicle loads beginning from the most remote customers on the distribution network and combining loads along a line to the transportation origin point.[35]

Such rules as those in the preceding list can be programmed into a model, often a computer software program, to allow the search for a solution to follow the logic of these rules.

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[33] Available at http://www.ennorefoundries.in.

[34] Charles L. Hinkle and Alfred A, Kuehn, "Heuristic Models: Mapping the Maze for Management," *California Management Review*, Vol. 10 (Fall 1967), p. 61.

[35] Ronald H. Ballou, "Heuristics: Rules of Thumb for Logistics Decision Making," *Journal of Business Logistics*, Vol. 10, No. 1 (1989), pp. 122–132.

Trend Micro Inc., engaged in developing network antivirus and Internet content security software, launched the enterprise spam prevention service (ESPS) to prevent unwanted e-mail through the Internet. This service was based on the heuristic technology antispam filtering rules of Postini Inc., engaged in e-mail security services.[36]

Optimization Models

Optimization models are based on precise mathematical procedures for evaluating alternatives and they guarantee that the optimum solution (best alternative) has been found to the problem as proposed mathematically. That is, it can be proved mathematically that the solution produced is the best. Many of the deterministic operations research, or management science, models are of this type. These include mathematical programming (linear, nonlinear, dynamic, and integer programming); enumeration; sequencing models; various calculus-dominated models; and equipment replacement models. Many optimization models have been generalized and are available as computer packages.

When do you use optimization models? According to Powers, "... wherever and whenever possible."[37] He goes on to note several advantages of the optimization approach:

- The user is guaranteed to have the best solution possible for a given set of assumptions and data.
- Many complex model structures can now be handled correctly.
- A more efficient analysis is conducted since all alternatives are generated and evaluated.
- Reliable run-to-run comparisons can be made, since the very best solution is guaranteed for each run.
- The cost or profit savings between optimum and heuristic-generated solution can be significant.[38]

Although these are impressive advantages, the optimization models are not without their disadvantages. The primary disadvantage is that, as the complexity of the problem increases, an optimum solution cannot be achieved within a reasonable computational time and with the memory capabilities of even the largest computers. Often, the realism of the problem description must be considered in trade-off with solution time. Even so, a limited optimization model might be used in a heuristic model, where optimization solves part of the problem. On the other hand, optimization models involving mathematical programming (a major type for network planning) frequently include heuristics to guide the solution process and limit solution time since they cannot guarantee that the solution will be

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[36] *Business Line* (March 18, 2003), p. 7.

[37] Richard F. Powers, "Optimization Models for Logistics Decisions," *Journal of Business Logistics*, Vol. 10, No. 1 (1989), p. 106.

[38] Ibid., pp. 111–115.

found without enumerating all possible alternatives with resulting unacceptable running time.

Example

A basic economic order quantity (EOQ) model that is used for inventory control is a good illustration of an optimization model. It is a calculus-based model that is very popular in practical application. Although of limited scope, it captures the essence of many inventory-control problems and is useful as a submodel within such planning models as a supply channel simulator. The EOQ model gives the optimum quantity of goods to reorder when the item inventory level drops to a predetermined amount. The model, which is a balance between the costs of ordering and the costs of carrying inventory, gives the optimum reorder quantity and has the following formulation:

$$Q^* = \sqrt{2DS / IC}$$

where

Q^* = optimum reorder quantity (units)
D = annual demand (units)
S = cost to procure order (dollars/order)
I = annual inventory-carrying cost (annual % of unit value)
C = value of a unit held in inventory (dollars/unit)

This model was discussed in Chapter 9.

Expert Systems Models

When a planning problem, such as network design, is solved many times in a variety of situations, the planner is likely to develop insight into how the problem is solved. Such insight often transcends the most complex mathematical formulation possible. This knowledge and expertise, if they can be captured in a model setting or expert system, can be used to produce solutions of higher overall quality than previously obtained with the use of simulation, heuristic, or optimization methods alone. Cook defines an expert system as

> an artificially intelligent computer program that solves problems at an expert level by utilizing the knowledge and problem solving logic of human experts.[39]

Although expert systems are in their early stages of development, some applications have been reported, such as aids to medical diagnosis, mineral exploration, designing custom computer configurations, and stacking boxes on pallets. A few applications in logistics are beginning to be reported in the areas of inventory, transportation,

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[39] Robert L. Cook, "Expert System Use in Logistics Education: An Example and Guidelines for Logistics Educators," *Journal of Business Logistics*, Vol. 10, No. 1 (1989), p. 68.

and customer service.[40] According to Cook, expert systems have several distinct advantages over conventional planning systems:

- They can process both qualitative and quantitative information, allowing critical subjective factors such as managerial judgment to more easily be part of the decision process.
- They can process uncertain information and provide solutions with only partial information, allowing more complex, unstructured problems to be solved.
- They provide solutions faster and at lower cost by using only the minimum information needed to solve a problem.
- They display the expert's problem solving logic, which allows the logistics manager to quickly improve decision-making capabilities.
- They provide portable, duplicatable, and documentable knowledge.[41]

Identifying experts, specifying the knowledge base (much of which may be qualitative), and acquiring their relevant knowledge are the greatest hurdles to be overcome in developing expert system models. Yet, the concept of capturing the techniques and knowledge associated with the artistry of planning in order to complement the scientific methods already used in planning has so much appeal that expert systems undoubtedly will increase in popularity.

Decision Support Systems

The database and the tools for analysis have been combined, with the aid of the computer, into what is now called a decision support system (DSS). A DSS aids the decision-making process by allowing the user to interact directly with the database, to direct data to decision models, and to portray results in a convenient form. According to Andersen, Sweeney, and Williams, a DSS has four basic subsystems:

- Interactive capability that enables the user to communicate directly with the system.
- A data manager that makes it possible to extract necessary information from both internal and external databases.

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[40] For example, see Mary K. Allen, *The Development of an Artificial Intelligence System for Inventory Management* (Oak Brook, IL: Council of Logistics Management, 1986); Robert L. Cook, Omar K. Helferich, and Stephen Schon, "Using an AI-Expert System to Assess and Train Logistics Managers: A Parts Inventory Manager Application," *Proceedings of the Sixteenth Annual Logistics Conference* (Anaheim, CA, October 5, 1986), pp. 1–24; Aysegul Ozsomer, Michel Mitri, and S. Tamer Cavusgil, "Selecting International Freight Forwarders: An Expert Systems Application, " *International Journal of Physical Distribution & Logistics Management*, Vol. 23, No. 3 (1993), pp. 11–21; James Bookbinder and Dominque Gervais, "Material-Handling Equipment Selection Via an Expert System," *Journal of Business Logistics*, Vol. 13, No. 1 (1992), pp. 149–172; Prabir K. Bagchi and Barin N. Nag, "Dynamic Vehicle Scheduling: An Expert Systems Approach," *International Journal of Physical Distribution & Logistics Management*, Vol. 21, No. 2 (1991); Lori S. Franz and Jay Woodmansee, "Computer-Aided Truck Dispatching Under Conditions of Product Price Variance with Limited Supply," *Journal of Business Logistics*, Vol. 11, No. 1 (1990), pp. 127–139; Peter Duchessi, Salvatore Belardo, and John P. Seagle, "Artificial Intelligence and the Management Science Practitioner: Knowledge Enhancements to a Decision Support System for Vehicle Routing," *Interfaces*, Vol. 18, No. 2 (March–April 1988), pp. 85–93; and Mary K. Allen and Omar K. Helferich, *Putting Expert Systems to Work in Logistics* (Oak Brook, IL: Council of Logistics Management, 1990), Chapter 3.

[41] Cook, "Expert System . . .," pp. 68–70.

- A modeling subsystem that permits the user to interact with management science models by inputting parameters and tailoring situations to specific decision-making needs.
- An output generator with a graphics capability that enables the user to ask what-if questions and obtain output in easily interpretable form.[42]

Such systems may simply provide an environment in which the decision maker may interact, but he or she is given substantial latitude in making a final choice. On the other hand, the DSS may give the solution that the decision maker is to implement. The former may be more typical when strategic planning is involved, whereas the latter may be more characteristic of operational planning. In either case, the computer-based DSS gives an extended dimension to the planning process.

Application

The Batesville Casket Company produces and distributes a line of premium caskets to funeral homes throughout the United States. Distribution takes place regionally from about 50 warehouses that domicile the trucks making daily deliveries to meet funeral home orders. Batesville developed a decision support system for its truck dispatchers. Orders from all over the country are entered into the company's mainframe computer at Batesville, Indiana. Overnight, the order quantities, along with customer location information, are transmitted to a microcomputer at the appropriate warehouse. Combined with information stored locally in the computer, the database manager within the system prepares the data in the form needed by a truck-routing and scheduling model. The local dispatcher calls upon this model to find good routes and schedules for the day's deliveries. He uses the model results as a first solution to his problem, modifying them according to late-arriving orders, changes in equipment availability, and modified customer requirements. He can test his revised plan against the optimized design before deciding his final delivery schedule.

CONDUCTING THE ANALYSIS

We now turn our attention to the logic used to strategically plan the logistics network. The network design problem is positioned at the very top of the planning hierarchy, as illustrated in Figure 14-7. It differs from other logistics planning problems in both the frequency with which the planning is repeated and the degree of aggregation in the information used in the planning process. To contrast network design from the other planning problems, consider how Stenger classifies the problems at each level in the hierarchy.

- ***Network design.*** Designing the network to accomplish the firm's strategic objectives. The number, location, product assignments, and capacities/capabilities of distribution centers, plants, and consolidation points are specified. Targets are set for inventory levels throughout the network. The level of customer service to be provided

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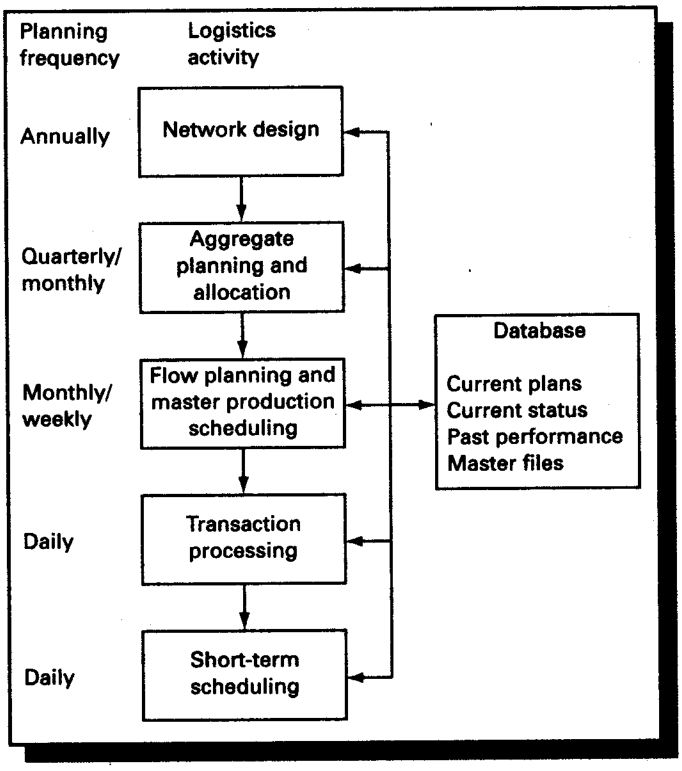
[42] David R. Andersen, Dennis J. Sweeney, and Thomas A. Williams, *An Introduction to Management Science*, 4th ed. (St. Paul, MN: West, 1985), p. 722.

Figure 14-7
A Hierarchy of Logistics Decision Making

Source: Adapted from Alan J. Stenger, "Electronic Information Systems—Key to Achieving Integrated Logistics Management," *Proceedings of the Seventeenth Annual Transportation and Logistics Educator's Conference* (Atlanta, GA, September 27, 1987), p. 16.



will be determined. Aggregate data and long-term forecasts are used and the planning process is not likely to be repeated in less than one year.

- ***Aggregate planning and allocation.*** Planning at this hierarchical level determines loads, or allocates demand to distribution centers, plants, and material sources on an aggregate basis. The aggregate volumes for purchasing, production, warehousing, and traffic are specified. Planning here is repeated quarterly or monthly.
- ***Flow planning and master production scheduling.*** Planning at this level is similar to the previous one, except that allocation is for the individual stock-keeping unit. The objective is to ensure that forecasts and inventory targets are being met. The planning horizon is monthly or weekly.
- ***Transaction processing.*** This is a short-term allocation planning problem whereby customer orders arriving in a random manner are assigned to be filled by location and carrier. Planning is daily.
- ***Short-term scheduling.*** A short-term planning problem that seeks to optimize the use of resources, such as transportation, to deal with specific open orders, while meeting explicit order processing deadlines. Planning is daily.[43]

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[43] Alan J. Stenger, "Electronic Information Systems—Key to Achieving Integrated Logistics Management," *Proceedings of the Seventeenth Annual Transportation and Logistics Educators Conference* (Atlanta, GA, September 27, 1987), pp. 12–26.

The procedures used for strategic planning do vary from planner to planner and from project to project. However, good practice can be generalized into at least several basic elements. Consider the general steps in this procedure.

Auditing Customer Service Levels

A logical, but optional, first step in designing a network is to conduct a customer service audit. This involves asking customers about the level of logistics service they are currently receiving and the level that they would like to receive. Personal interviews with customers or mail questionnaires are typically used to answer such questions as

- What levels of service do customers expect?
- What levels of service do competitors provide?
- How do competitors achieve their service levels?
- To what extent has the firm assured itself that its strategy meets desired levels of costs and services to end users?
- To what extent has the firm employed "channel vision" in determining who should do what, when, where, and how in its channels of distribution?
- Does the firm's logistics strategy support its corporate strategy?[44]

This type of audit can help to establish the target logistics customer service level for the network design; however, it is quite common for service levels to be specified by management or to be set at the existing levels.

The external audit may be followed by an internal one. The purpose is to establish the level of service that the firm is actually providing and to define a benchmark for service. Sterling and Lambert suggest that the internal audit should answer the following questions:

- How is customer service currently measured within the firm?
- What are the units of measurement?
- What are the performance standards or objectives?
- What is the current level of attainment—results versus objectives?
- How are these measures derived internally?
- What is the internal customer service reporting system?
- How does each of the firm's business functions perceive customer service?
- How do these functions interface in a communications and control context?
- What is the variance in order cycle time, and how does this variability impact on the customer's business?[45]

Although it would be beneficial to conduct such an internal audit, most planners do not do it. Rather, they are more likely to rely on replicating the current network design as the best indication of the current customer service levels that the firm is providing.

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[44] Jay U. Sterling and Douglas M. Lambert, "Customer Service Research: Past, Present and Future," *International Journal of Physical Distribution & Materials Management*, Vol. 19, No. 2 (1989), pp. 1–23.
[45] Ibid.

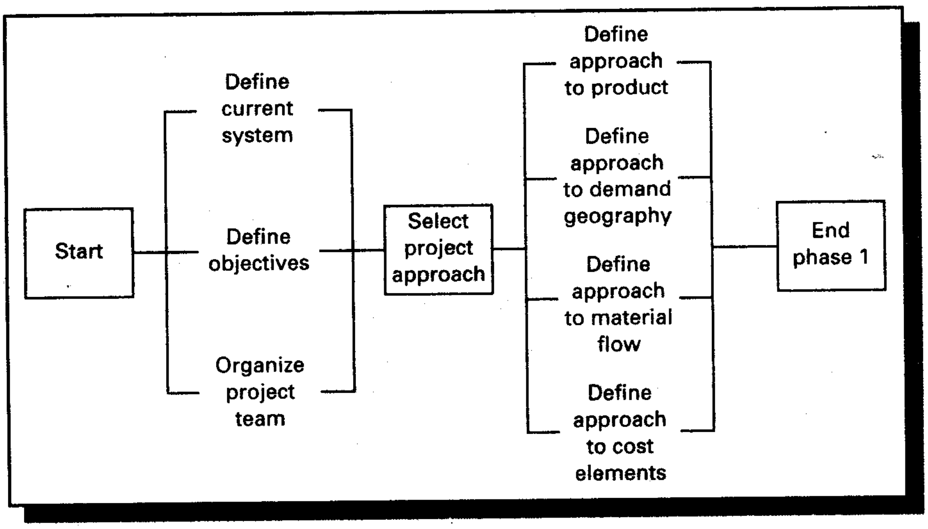

Figure 14-8 Logistics Network Design, Organization Phase

Source: Frank H. Mossman, Paul Bankit, and Omar K. Helferich, *Logistics Systems Analysis*, rev. ed. (Washington, D.C.: University Press of America, 1979), p. 307.

It would be ideal if these audits could generate a reliable relationship between the customer service levels and the resulting revenues that would be realized from a particular network design. Since they rarely do, it is common to treat customer service as a *constraint* on the network design. The constraint can be changed to see the effect on total costs and, thereby, indirectly impute the worth of service.

Organizing the Study

The first phase of network design typically involves defining the scope and objectives of the project, organizing the study team, determining the availability of needed data, and establishing the collection procedures. The purpose is to determine the feasibility of conducting a strategic planning study within a particular situation, the appropriate members to be included on the study task force, and the likelihood of the study having useful results. Mossman, Bankit, and Helferich have summarized this initial study phase (see Figure 14-8) and have given a description of the tasks involved:

- Review the present logistics situation to define costs, customer service levels, and logistics operations to provide a basis for evaluating logistics system alternatives (the logistics audit).
- Interview key management personnel and each member of the project team to ensure understanding of management objectives and to gain background for defining the specific questions and logistics systems alternatives to be evaluated in the study.
- Develop a preliminary list of critical management study assumptions, logistics operating and marketing policies, and guidelines that are critical to the evaluation of logistics alternatives and to the data collection effort.

- Specify the required evaluation criteria and study the output in terms of cost and customer service variables.
- Select the solution technique (model) based on the appropriateness for the alternatives to be evaluated, ease of preparing input data, cost and time estimates, and projected future utilization.
- Define the specific data requirements and provide the data collection procedures.
- Outline any major manual analyses required to supplement the computer model results to further evaluate the impact on cost and customer service.
- Conduct a working meeting with the project team to review findings, conclusions, model selection criteria, and preliminary project work plan.
- Estimate the benefits in terms of cost reduction (profit improvements) or customer service improvements expected from the study.
- Recommend, as appropriate, any suggestions for immediate cost or customer service improvements.
- Define project management procedures and estimate the personnel, computer, and other support requirements of the study.[46]

The task force should be organized with an eye toward strategy implementation. Careful attention should be given to including those people whose areas may be affected by the study and who may provide valuable insights and judgments as needed. It is particularly important to include persons from the production and marketing areas.

Benchmarking

Benchmarking, or validation of the modeling or other analytical processes used in planning, is the second phase of strategic planning. The philosophy here is to create a reference point, or base case, using a firm's current distribution patterns and policies. The methods used for analysis should be reasonably close to what standard accounting and reporting procedures produce. In addition to establishing the cost of the current distribution system so that changes may be made against it, the benchmarking process builds confidence that the methods used will accurately portray the firm's distribution costs and customer service performance.

Modeling is a popular approach to the network design problem, and benchmarking serves an important role in the analytical process. Analysis is directed at making comparisons between the network in its current configuration and a new, improved network configuration. Of course, management would like the comparisons to reflect actual conditions under which they must operate. However, models are much easier to manipulate than an actual network, so we use modeling as a way of making comparisons. The comparison of model results is a surrogate for what would be expected in actual practice. Therefore, benchmarking is the process whereby we validate that the modeling process faithfully replicates the cost and service levels of the current network. This builds confidence that when the model represents network configurations not now experienced by management, it will match to a reasonable degree the cost and service levels in practice.

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[46] Frank H. Mossman, Paul Bankit, and Omar K. Helferich, *Logistics Systems Analysis*, rev. ed. (Washington, D.C.: University Press of America, 1979), Chapter 8.

Benchmarking typically proceeds in the following manner: Representative product groups are established. The number is determined as a balance between retaining the distinctive characteristics of the products with regard to service and costs, and the benefits of reduced data collection resulting from product aggregation.

Next, sales are aggregated geographically into a manageable number of demand centers. Customer service policies are defined for each product group. Data are collected for relevant cost categories, such as transportation, warehousing, inventories, and production/purchase. Current product-flow paths are described for both movements through the warehouse as well as movements from plants/vendors/ports directly to customers. Inventory policies are also defined at this time.

Finally, various relationships between cost, demand, and service are established from the collected data. The information is organized in cost-service categories to be compared to actual expenditures made. The task force reviews the reasonableness of these results attempts to explain any deviations. Once this validation process is complete, selection of the best system design can begin.

Network Configuration

The modern approach to network configuration planning is to use the computer to manipulate the substantial amounts of data involved in the analysis. Computer models that deal with the problem of location in network planning have been particularly popular. They have been useful in answering questions that relate to the number, size, and location of plants, warehouses, and terminals; the way demand is assigned to them; and the products that should be stored at each facility. The objectives for network configuration are to

- Minimize all relevant logistics costs while meeting the constraints on logistics customer service.
- Maximize the logistics customer service level while holding the line on total logistics costs.
- Maximize the profit contribution made by logistics by maximizing the spread between the revenues generated by a logistics customer service level and the costs for providing that level of service.

The third objective is more in keeping with a firm's economic goals, but, due to the frequent lack of a sales and service relationship for the firm's products, most models are built around the first objective.

Models that help the planner search for the best configuration of facilities will do so by attempting to balance conflicting cost patterns that occur among production/purchasing, warehousing, and transportation, subject to practical limitations such as plant capacity, warehouse capacity, and customer service restrictions. The costs are associated with product movements as they take place from plants and vendors through intermediate stocking points and on to customer locations. An example of the type of output report that can be obtained from a commercial-grade model for location analysis is shown in Figure 14-9. This summary report is a result of one computer run where the user specifies the facilities and the manner in which the product

Figure 14-9 Sample Output for One Product Group from a Commercial-Grade Facility Location Model

```
ANALYSIS OF PRODUCT -- Canned goods-EU

                       -SUMMARIZED NETWORK SOLUTION RESULTS-
Revenue                                     E$                                 0
Production/purchase cost                                        13,425,407
Level 3 facility operating cost                                          0
Level 3 facility fixed cost                                              0
Level 3 facility inventory carrying cost                                 0
Level 2 facility operations cost                                         0
Level 2 facility fixed cost                                              0
Level 2 facility inventory carrying cost                                 0
Level 1 facility operations cost                                   243,478
Level 1 facility fixed cost                                        160,000
Level 1 facility inventory carrying cost                           283,761
  Transportation cost:
Plants/vendors to level 3 facilities                                     0
Plants/vendors to level 2 facilities                                     0
Plants/vendors to level 1 facilities                               584,014
Plants/vendors to customers                                              0
Level 3 to level 2 facilities                                            0
Level 3 to level 1 facilities                                            0
Level 3 facilities to customers                                          0
Level 2 to level 1 facilities                                            0
Level 2 facilities to customers                                          0
Level 1 facilities to customers                                 11,533,930
  Total cost                                                    26,230,590

    Profit contribution                     E$                       -26,230,590

                             -CUSTOMER SERVICE PROFILE-
Dist. from                                  Dist. from
facility to        Percent of  Cum. % of   facility to       Percent of   Cum. % of
customer, (Km)     demand      demand      customer, (Km)    demand       demand
   0.0 to 100.0         .0          .0       800.0 to   900.0    42.6          73.8
 100.0 to 200.0         .0          .0       900.0 to 1,000.0      .0          73.8
 200.0 to 300.0       12.1        12.1     1,000.0 to 1,500.0     2.2          76.0
 300.0 to 400.0        3.3        15.4     1,500.0 to 2,000.0    24.0         100.0
 400.0 to 500.0        4.1        19.5     2,000.0 to 2,500.0      .0         100.0
 500.0 to 600.0       11.7        31.2     2,500.0 to 3,000.0      .0         100.0
 600.0 to 700.0         .0        31.2              > 3,000.0  ______.0       100.0
 700.0 to 800.0         .0        31.2                  Total   100.0

                    -PLANT/VENDOR THRUPUT AND ASSOCIATED COSTS-
Plant/            Plant/                                                Plant/
vendor            vendor           Maximum           Assigned           vendor
number            location         thruput, Kgr      thruput, Kgr       cost, E$
  1               PARIS              200,000            69,712         2,180,591
  2               ROME               400,000           354,950        11,244,816
                  Totals             600,000           424,662        13,425,407
```

Figure 14-9 (*cont.*)

```
Plant/               Plant/      --------Transport Costs from Plants/Vendors--------
vendor               vendor      To level 3, To level 2, To level 1,  To customers,
number               location    E$          E$          E$           E$
  1                  PARIS            0           0       131,630           0
  2                  ROME             0           0       452,384           0
                     Totals           0           0       584,014           0

                     -LEVEL 1 FACILITY THRUPUT AND ASSOCIATED COSTS-
Level 1         Level 1         Maximum        Assigned        Storage        Handling
facility        facility        thruput,       thruput,        costs,         costs,
number          location        Kgr            Kgr             E$             E$
  1             MILAN             900,000       354,950          57,080        141,980
  2             LIVERPOOL         900,000        29,411           7,010         16,176
  3             HANNOVER          900,000        40,301           5,918         15,314
                   Totals       2,700,000       424,662          70,008        173,470

Level 1       Level 1       Facility       Estimated       Inventory      Transport-
facility      facility      fixed          inventory       carrying       Level 1 to
number        location      costs, E$      level, E$       costs, E$      customers, E$
  1           MILAN           50,000       1,364,567        231,976        11,418,378
  2           LIVERPOOL       80,000         131,685         22,387            52,648
  3           HANNOVER        30,000         172,928         29,398            62,904
                 Totals      160,000       1,669,180        283,761        11,533,930

                         -CUSTOMER ASSIGNMENTS TO FACILITIES-
                                      Serving      Serv.      Serv.     Serv.   Landed
Volume,   Seq   Customer      Seq     point        point      dist.,    time,   cost,
Kgr       no.   location      no.     location     type       Km        Days    E$/Kgr
 38,955    1    LISBON         1      MILAN        LVL 1      1,930     .00     133.31
148,384    2    BARCELONA      1      MILAN        LVL 1        837     .00      36.09
 14,035    3    LONDON         2      LIVERPOOL    LVL 1        316     .00      39.24
 22,966    4    BERLIN         3      HANNOVER     LVL 1        295     .00      36.61
 19,794    5    BRUSSELS       1      MILAN        LVL 1        842     .00      36.10
 49,891    6    ROME           1      MILAN        LVL 1        535     .00      35.66
 15,376    7    DUBLIN         2      LIVERPOOL    LVL 1        277     .00      39.13
 17,335    8    COPENHAGEN     3      HANNOVER     LVL 1        461     .00      36.97
 12,537    9    BORDEAUX       1      MILAN        LVL 1        868     .00      36.14
  9,327   10    PALERMO        1      MILAN        LVL 1      1,004     .00     133.31
 62,993   11    ATHENS         1      MILAN        LVL 1      1,694     .00     133.31
 13,069   12    LUCERNE        1      MILAN        LVL 1        239     .00      35.23

                    -LEVEL 1 FACILITY ASSIGNMENTS TO SERVING POINTS-
                Level 1               Serving      Serv.      Serv.     Serv.   Thruput
Volume,   Seq   facility      Seq     point        point      dist.,    time,   cost,
Kgr       no.   location      no.     location     type       Km        Days    E$/Kgr
354,950    1    MILAN          2      ROME         PLANT        563     .00      34.31
 29,411    2    LIVERPOOL      1      PARIS        PLANT        719     .00      37.39
 40,301    3    HANNOVER       1      PARIS        PLANT        762     .00      35.20
```

flows through them or the model makes the facility selections and allocates to them. The network is potentially like that represented in Figure 14-1. Note that no regional warehouses are specified in this solution, only field, or level 1, warehouses.

Establishing Benchmark Costs and Service Levels

The first step in strategic network planning is to establish a benchmark of existing logistics costs and service levels. Surprisingly, few firms have carefully described

Table 14-6 Summary of Selected Results from a Network Analysis for a Specialty Chemical Company

	MODEL RUN TYPE[a]			
COST TYPE	BENCHMARK	IMPROVED BENCHMARK[b]	MAX. SAVINGS NETWORK[c]	IMPLEMENTABLE NETWORK[d]
Inventory and warehousing				
Capital	$ 103,110	$ 87,008	$ 87,626	$ 100,737
Tax and insurance	38,756	47,957	19,037	34,022
Order processing	284,366	223,820	198,210	262,413
Storage	165,788	138,412	119,749	119,293
Handling	299,863	265,252	329,385	253,479
Subtotal	$ 891,883	$ 762,449	$ 754,007	$ 769,944
Transportation				
Plant to warehouse	$ 261,853	$ 213,567	$0	$ 206,542
Warehouse to customer	1,041,661	1,113,978	1,453,812	925,043
Subtotal	$1,303,514	$1,327,545	$1,453,812	$1,131,585
Production	At current capacities →		← No capacity restrictions	
@Atlanta	$3,861,765	$3,906,037	$ 832,112	$3,404,138
@Indianapolis	667,057	593,876	770,427	906,619
@Houston	587,140	498,835	2,408,764	692,441
Subtotal	$5,115,962	$4,998,748	4,011,303	$5,003,198
Total	$7,311,359	$7,088,742	$6,219,122	$6,904,727
Customer Service	Closely matched		No restriction	
Percentage of demand				
< 300 miles	65%	63%	30%	68%
< 500 miles	85%	82%	45%	98%
No. of warehouses	9	9	3	10
Savings vs. benchmark	0	$ 222,617	$1,092,237	$ 406,632[e]

[a] Costs are totals for three product groups.

[b] Plant capacity restrictions are at current levels but with no service restrictions. The result is direct shipments from plants.

[c] No plant capacity or customer service restrictions. The result is direct shipments from plants.

[d] Current plant capacities are in effect and the desired service level is set at 500 miles.

[e] Essentially no investment in plant or warehousing is required to realize these savings.

their distribution flow patterns, customer service performance, or the total costs of distribution. This process sets the base level of costs, service, and configuration against which improvements may be compared, as shown in Table 14-6. The results may be used to validate the modeling process as well as to increase confidence that the projected cost improvements will be accurate.

Improved Benchmark

Over time, such occurrences as demand shifts, transport rate adjustments, and warehouse storage and handling rate changes may cause an otherwise well-planned network design to perform at a suboptimal cost-service level. Therefore, the next task in strategic network planning is to optimize the logistics patterns subject to the existing number and location of facilities, capacities of those facilities, current service levels, and the like. This is a no-investment strategy, where cost savings may be realized without an outlay of capital. As Table 14-6 shows, a specialty chemical company could realize more than $400,000 per year in cost savings (implementable network) from a total benchmark cost of $7.3 million, a reduction of 6 percent, by increasing the number of stocking points used and allowing customer service to be brought in line with stated service policy. This is an important result because further alterations to the network are properly compared with the improved benchmark rather than the benchmark cost level.

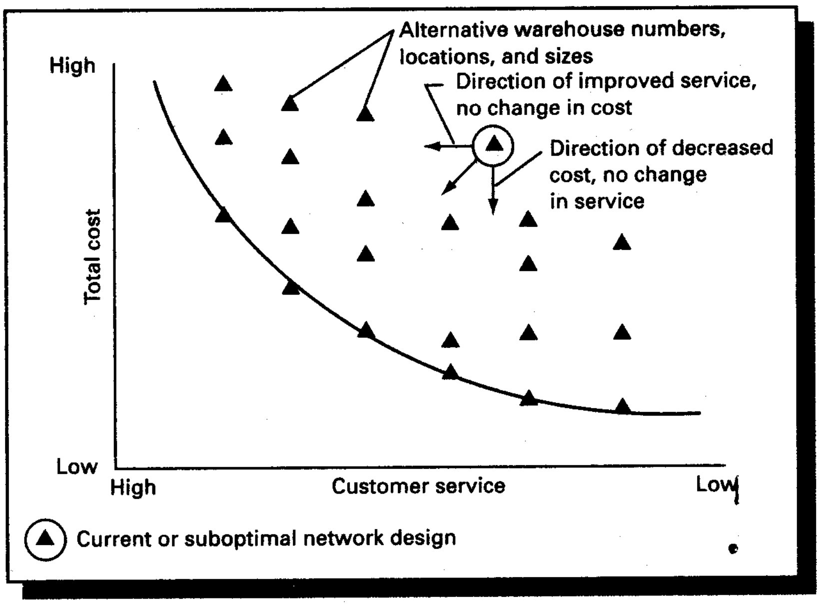
Maximum Opportunity

In strategic network planning, it is informative to determine the network with the lowest possible variable costs. This is accomplished by finding the optimum network without plant or warehouse capacity constraints, without customer service restrictions, and considering a large number of plant and warehouse locations. As Table 14-6 indicates, this result, although attractive from a cost savings standpoint, is usually achieved through reduced service and a shifting of demand to facilities beyond their capacity to handle it. Obviously, if these savings were not great enough to support a change beyond the improved benchmark, further exploration of alternatives would likely be fruitless because they would only have higher costs.

Practical Designs

Between the improved benchmark and the maximum savings design, there may be a number of acceptable network strategies. These may be found through repeated model runs that represent various network configurations and assumptions about demand, costs, and service. These configurations can produce a combination of cost and service levels, as shown in Figure 14-10. That is, for any given service level, there may be many different numbers of warehouses and their locations (configurations) that can realize a particular service level, but with different cost levels. Drawing a smooth line through the lowest cost points generates a network design curve that identifies the lowest cost alternative for each service level (see Figure 14-10). It is along this design curve that we seek an improved network configuration. If a current design is not optimal and, therefore, it lies above the design curve, then moving the design to the left increases customer service without increasing costs. Moving the

Figure 14-10
A Design Curve for Network Configuration Generated from the Lowest Cost Alternatives for a Particular Customer Service Level



design point down lowers costs while maintaining the same customer service level. Moving the design point to the design curve affords the maximum opportunity for cost or service improvement.

The costs and service results for one such practical design are shown in Table 14-6. Note that in this case the company chose a conservative design where the number of stocking points and the customer service level were higher than that of the benchmark and the improved benchmark. The savings were still substantial at over $400,000 per year—more than 5 percent of total production and distribution costs. There was also some improvement in the logistics customer service level.

What-If Analysis

There will always be errors in estimating cost and capacity input information for network planning. There may be attractive designs that are suboptimal from a modeling standpoint, but better reflect practical considerations beyond the modeling process. Repeating the analysis using selected network scenarios and/or revised cost and capacity figures is referred to as *what-if analysis*. It is a way of using the analytical process to assist in bringing more reality into the search for a practical network design. What-if analysis is often considered more valuable to management than the modeling process's ability to find an optimal solution to a given set of data. This is because there is often little cost difference between closely configured networks, and because an improved network design around which the organization can rally is usually more valuable than a mathematically optimum solution.

Comparable Data[47]

It seems appealing to use actual company data to design a network, but this may lead to a biased design. Suppose that a warehouse in a company's distribution network that may be poorly located has low per unit costs owing to its current high throughput volume and the related spreading of its fixed costs. On the other hand, another warehouse has a good location, but has been assigned high per unit costs due to its underutilization. If these costs are used in revising the network, the poorly located warehouse may survive and the other may be closed or continue to be underutilized. A similar situation may occur between rates assigned to existing warehouses and potential ones that would be new and have the most modern equipment.

A remedy for this kind of data incomparability is to assign a standard rate to each warehouse that neutralizes the effects of age and size, but preserves the cost differentials that are due to location. Of course, standardizing the rates in this manner may drive demand away from existing warehouses where there is a high sunk cost and an emotional investment by management. A choice must be made here.

Design Year Analysis

Ideally, designing or redesigning a network is based on some period in the future, since a new design cannot be implemented instantly. Of course, a forecast of demand can be made to the design year. A major question is whether costs should also be projected to the design year. Except for demand forecasting, projecting costs into the future results in losing touch with the benchmark and its associated comparability. It is usually a better practice to hold costs constant unless they are changed in the benchmark as well.

Channel Design

Configuration of the network mainly concerns location questions, where issues relating to inventory and transportation are dealt with on an aggregate level. There are several additional considerations regarding how the products should be directed through the configured network. Products flowing through a typical logistics/supply channel, like that shown in Figure 14-11, raise some of the following questions:

- How much of each product item should be stocked at each echelon and at each stocking point?
- What is the best transport service to use between each echelon?
- Should a make-to-order or make-to-stock strategy be followed?
- Should a push or pull inventory strategy or requirements planning be used?
- What methods of information transmittal between stocking echelons are best?
- Which forecasting methods perform best?

Therefore, channel planning is concerned with planning the configured network operation. The best design approach is to consider network configuration and channel design simultaneously. This is a very difficult problem, because the fundamental dimensions on which each is based are quite different. Network configuration is primarily based on a *spatial*, or geographic, dimension whereas channel design is based

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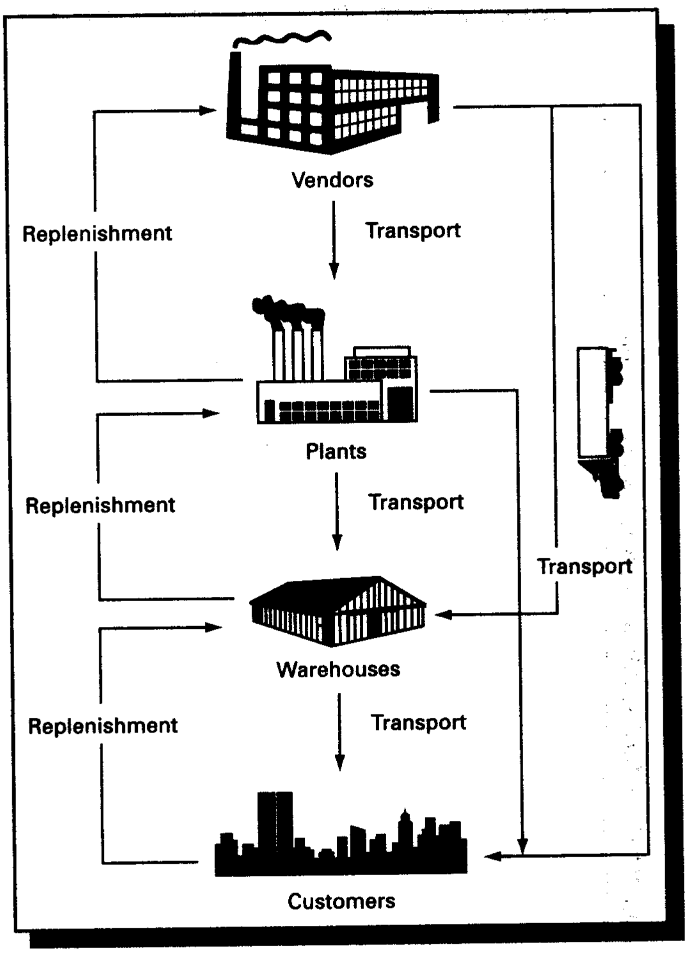
[47] This section based on Ballou, "Information Considerations," p. 12.

Figure 14-11
A Multi-Echelon Logistics/Supply Channel



on a *temporal*, or time, dimension. Although combining spatial and temporal issues into a singular analysis is ideal, practical considerations require that they be treated separately and then worked iteratively to achieve a satisfactory overall design.[48] Because there are no effective, integrated models that deal with the entire strategic supply chain planning problem, it is usually necessary to break down the complex problem into manageable portions. This has meant solving facility location, inventory policy, and transport planning problems separately but recursively, where the results of one analysis are used as inputs to another. The process quickly converges on a satisfactory answer to the comprehensive problem.

A primary method for channel planning involves the use of computer simulation of the supply chain channel. The action of such simulators is to closely mimic the flow of orders and product through a configured network. Orders are generated in

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[48] Waiman Cheung, Lawrence C. Leung, and Y. M. Wong, "Strategic Service Network Design for DHL Hong Kong," *Interfaces*, Vol. 31, No. 4 (2001), pp. 1–14.

Figure 14-12 An Illustrative Summary Report from PIPELINE MANAGER, a Supply Channel Simulator

```
PIPRPT01
                                                     ABC Manufacturing Co.
                                                        Pipeline Manager
                                                      Run Summary Report

   Run Number: 001      Total Model Run Days: 364                   #Items: 17    #Finished Goods Warehouses: 03
  Random Seed: 002             Total Periods: 13                  #Vendors: 05           #Central Warehouses: 01
                           Steady-State Days: 028     #Raw Material Warehouses: 03   #Customer Facing Warehouses: 05
                                                                     #Plants: 03                  #Customers: 20

                                       Customer                  Finished                  Raw
                                       Facing       Central      Goods                     Material
Statistic                 Customers    Warehouses   Warehouses   Warehouses   Plants       Warehouses   Vendors      Totals
--------------------------------------------------------------------------------------------------------------------------------
Sales                       105,300,000                                                                              105,300,000

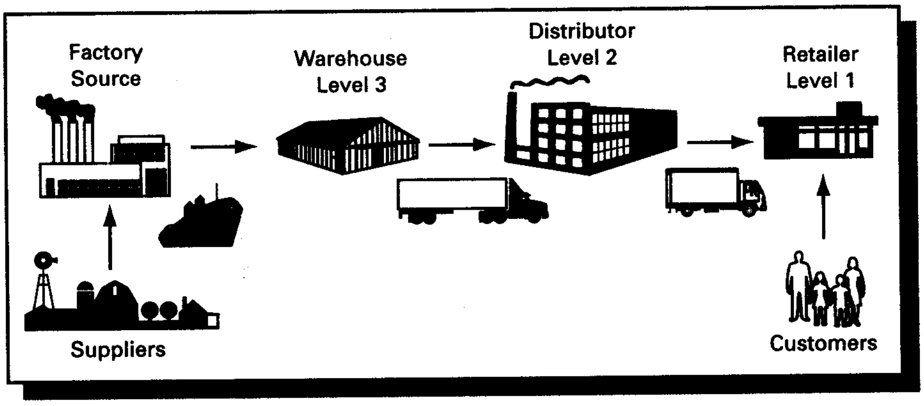
Costs:
  Purchase                                                                                               40,000,000   40,000,000
  Production                                                               15,000,000                                 15,000,000
  Shipping                                4,000,000    3,500,000    2,500,000      750,000      800,000               11,550,000
  Warehousing                             3,500,000    2,800,000    3,000,000    1,500,000    2,500,000               13,300,000
  Inv. Carrying                           1,250,000      750,000      800,000                   600,000                3,400,000
  Order Processing                          900,000      550,000      400,000                   450,000                2,300,000
  Total Costs                                                                                                         85,550,000

Margin                                                                                                                19,750,000

Cust. Service Level                 87%                                                                                      87%
Fill Rate                                       90%          85%          93%          84%          86%                      89%
Avg. Lead Time (Days)               4.8          4.5          6.8          6.3          8.4          2.4         22.0         55.2
Inventory Turnover                               8.4         20.2         35.0                      18.5                      4.3
```

Avg. Inv. Units		150,200	62,600	44,700		81,000	298,000
Avg. Inv. $ Value		12,500,000	5,200,000	3,700,000		2,400,000	23,800,000
#Orders Placed	12,200	960	200			180	13,540
#Order Units Placed	1,300,000	1,285,000	1,310,000			1,296,000	5,191,000
Avg. Size (Units)	106	1,340	6,500			6,700	380
Avg. Size ($)	8,840	110,000	540,000			230,000	31,800
#Shipments Received	12,500	965	195	2,200	2,210	690	18,760
#Units Received	1,281,250	1,230,000	1,275,000	1,280,000	1,285,000	1,250,000	7,601,250
Avg. Size (Units)	103	1,275	6,540	580	581	1,800	405
Avg. Size ($)	8,510	100,000	545,000	48,300	18,350	58,000	32,400
			10,750				
#Backorders	845	850	55	45	450	350	1,750
#BO Units	71,500	85,000	48,400	171,000	270,000	206,500	782,650
Avg. Size (Units)	85	100	880	3,800	600	590	447
Avg. Size	7,565	8,100	73,000	317,000	49,800	19,000	35,780
#Splits & Partials	370	550	480	190			1,220
#Split/Part Units	38,850	35,000	28,000	15,200			78,200
Avg. Size (Units)	105	63	58	80			64
Avg. Size ($)	7,350	5,280	4,100	6,640			5,320
#Cancellations	150						150
#Cancelled Units	18,750						18,750
Avg. Size (Units)	125						125
Avg. Size ($)	10,750						10,750

Figure 14-13 Simulated Channel for SCSIM



patterns similar to those a company actually experiences. Given a specific network configuration, its operating procedures, and policies, its transport services, and its customer service policies, product is tracked through the channel to meet the simulated order patterns. Sales, costs, and lead time statistics are typically captured by the simulation. Representative summary information generated by such a simulator is shown in Figure 14-12. By changing such elements as the method of forecasting sales, the modes of transportation, the inventory-control policies, and the methods for filling orders, the status of the channel design to meet customer service requirements in an efficient manner can be evaluated.

Channel Simulation in LOGWARE

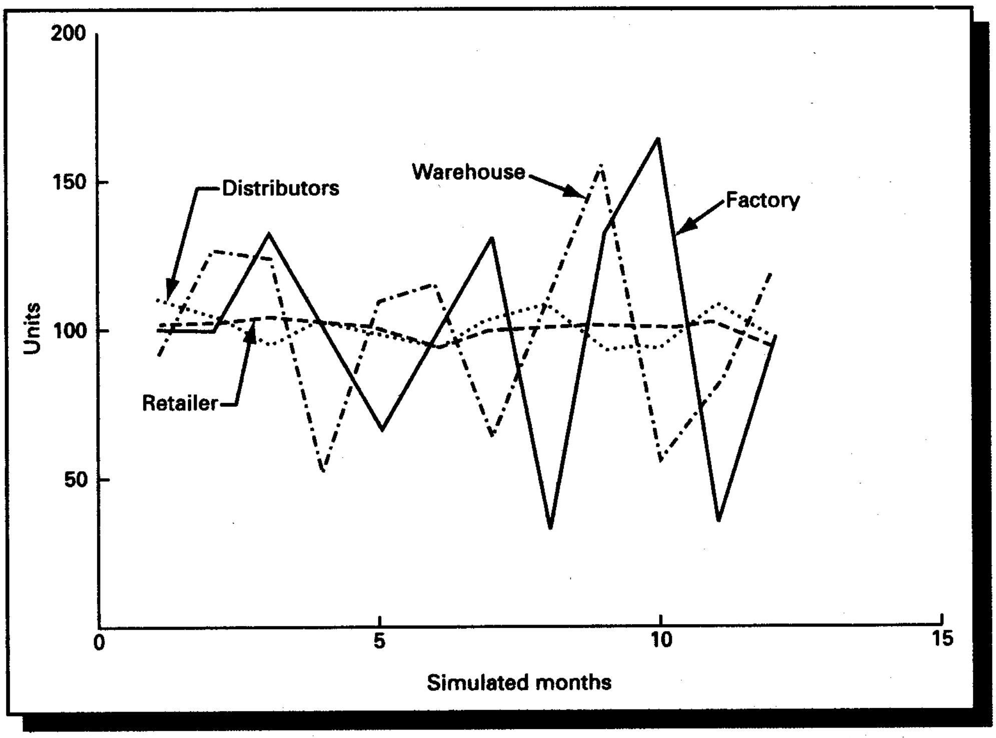
A stochastic simulator called SCSIM is available in the LOGWARE software that accompanies this textbook. It has the capability of replicating the operating characteristics of a supply channel having the multiple echelons shown in Figure 14-13. Because the simulation is multi-echelon, the effect of the channel policies of one or more channel members can be tested for the effect on other members. Operating costs and performance factors describe the modes of transportation, order processing, and manufacturing. Different methods of forecasting and inventory control can be used with manual inventory control and user forecasting, if desired. Demand patterns can be specified, or they can be generated using statistical patterns. Product fill rates can be specified, or are the result of product flowing through the channel.

To run a simulation, prepare the database as instructed in the user's manual. There are at least two concerns to be aware of when running a stochastic simulator. First, recall that simulations should be treated as experiments. That is, conclusions result from a number of runs, or trials, that are analyzed statistically using hypothesis testing. Randomly selecting a seed number gives the result for one experiment, or trial. Using the same seed number produces the same result if no changes have been made in the database. Choosing a different seed number gives a different event sequence with different experimental results. A reasonable sample size (number of runs) should be obtained with the appropriate averaging of the results and statistical testing to compare one supply channel design to another.

The second concern is the length of simulated time. Simulations are subject to start-up conditions such that taking the results from early periods can give erroneous impressions. The simulation needs to be run for a sufficient time until steady-state conditions are reached. Plotting run results can show the initial unrepresentative periods, which can be eliminated. For example, if the simulation length is set to be five years, it may be reasonable to accept results from years 2 through 5. Year 1 results are sacrificed. For additional considerations in using simulators as analytical tools, refer to a good book on simulation modeling.[49]

To illustrate the use of the simulator, consider the "bull whip" effect that occurs in supply channels. In a multi-echelon supply channel where each member derives its demand pattern from the orders of the immediate downstream member, it is said that the demand patterns show increasing variability with each successive upstream member.[50] The uncertainty of increasing demand variability can cause poor planning and high operating costs. The "bull whip" phenomenon can be illustrated using the

Figure 14-14 Illustration of Increasing Demand Variability ("Bull Whip" Effect) in a Multi-Echelon Supply Channel



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[49] For example, see Averill M. Law and W. David Kelton, *Simulation Modeling and Analysis*, 3rd ed. (New York: McGraw-Hill, 2000), especially Chapters 5 and 10.

[50] Frank Chen, Zvi Drezner, Jennifer K. Ryan, and David Simchi-Levi, "Quantifying the Bullwhip Effect in a Simple Supply Chain: The Impact of Forecasting, Lead Times, and Information, *Management Science*, Vol. 46, No. 3 (March 2000), pp. 436–443.

SCSIM simulator. Tracking sales through a supply channel consisting of a production point serving a warehouse serving a distributor serving a retailer, who finally serves the end customer (see Figure 14-13) gives the sales plot shown in Figure 14-14. A representative sales pattern for a simulated year is shown for each channel member. Notice the increasing oscillations for the upstream members. Some of the ways that the sales patterns can be smoothed and channel planning improved include:

- Reduce uncertainty throughout the channel by centralizing information, thereby making critical planning information, especially customer demand data, available to all members
- Plan echelon inventory levels on end-channel (customer) demand
- Improve forecasting
- Reduce lead times
- Improve inventory decision rules
- Form partnerships and collaborate on order sizes, deliveries, and order timing

The simulator is useful to test the effect of changing inventory decision rules, transportation modes, order-processing procedures, and forecasting methods without disturbing actual operations. The cost-service implications can be seen for the entire channel as well as for individual channel members.

Integrated Supply Chain Planning

Comprehensive supply chain planning is a process involving several elements, a number of which have previously been discussed in this chapter. Unless the relationship between customer service and logistics design is known, planning starts with determining a target customer service level. A survey of customer desires or a specified customer service level is needed. After assembling the appropriate data, analysis can begin.

Good planning involves both network configuration and channel design. Integration of these two is not generally achieved using a single model.[51] However, a network model can be used in concert with a channel simulator. Preliminary results for the number of facilities, their locations, and allocated volume to them are found from applying a location model. Then, these results are provided to the channel simulator so that inventory effects, transport mode analysis, and fill rate levels can be evaluated. Revised inventory-throughput relationships, transport modes with associated rates, and facility costs are inputted into the location model for reevaluation. Solving the two models recursively continues until there are no longer changes in the model inputs and outputs. This process allows converging on an optimal, or nearly optimal, solution to the integrated location-channel planning problem. However, in practice, most supply chain planning is conducted using only the location analysis while estimating the effects on operation issues.

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[51] For an early attempt at creating a single planning model, see Donald J. Bowersox et al., *Dynamic Simulation of Physical Distribution Systems* (East Lansing, MI: Division of Research, Graduate School of Business Administration, Michigan State University, 1972).

A LOCATION CASE STUDY

To illuminate some of the major ideas presented in this chapter, consider the process of evaluating and making recommendations for the production and warehousing system of a specialty chemical company. Special attention is given to how various data elements were obtained and treated, the methods used to converge upon a final recommendation, the practical restrictions that had to be considered for a satisfactory solution, and the reporting of the results to management.

Problem Description

Aqua-Chem Company produced a line of water treatment chemicals that were used to control mineral deposits in boilers, algae formation in commercial air-conditioning systems, and bacteria growth in swimming pools. Customers were located throughout the United States; sales approximated $15 million per year for about 21 million pounds of chemicals. The company grew dramatically through the acquisition of similar small, regional firms, which eventually gave it market coverage of the entire country. Product distribution was continued from the acquired plants as it had been before acquisition. Six such companies and plants were merged under this program, but no systematic review of the entire logistics system had ever been made. Therefore, a supply chain network study was proposed to suggest improvements in the flow of product to customers.

The first order of business was to form a task force of company and consulting personnel who would guide the study. This group consisted of the director of purchasing, the vice president of marketing, the controller, the traffic manager, an analyst from the planning department, and a professor of logistics from a local university who would act as a consultant to the group. Priority was given to defining the scope of the study. Because purchasing costs play an important role in determining the final distribution network, all costs from the major vendors, through production of the products and on to the customer, were considered. Depending on whether the products were ordered by customers in full-truckload quantities or in less-than-truckload quantities, separate supply chain networks would have to be considered. Volume purchases would be shipped directly from one of the six plants located at Portland, Oregon; Phoenix, Arizona; Minneapolis, Minnesota; Dallas, Texas; Asheville, North Carolina; or Akron, Ohio. Smaller orders would be served from warehouses or from plants acting as warehouses for their local territories. The costs associated with each of these distribution channels are summarized in Figure 14-15.

Managing the Problem Size

The company distributed hundreds of individual product items to thousands of customers. Due to the enormous amount of data required, it was necessary in this study, as well as in most distribution studies, to make selective simplifications that reduce computational effort while retaining accuracy in representing the problem. First, rarely does all product volume need to be included in the study. Many products

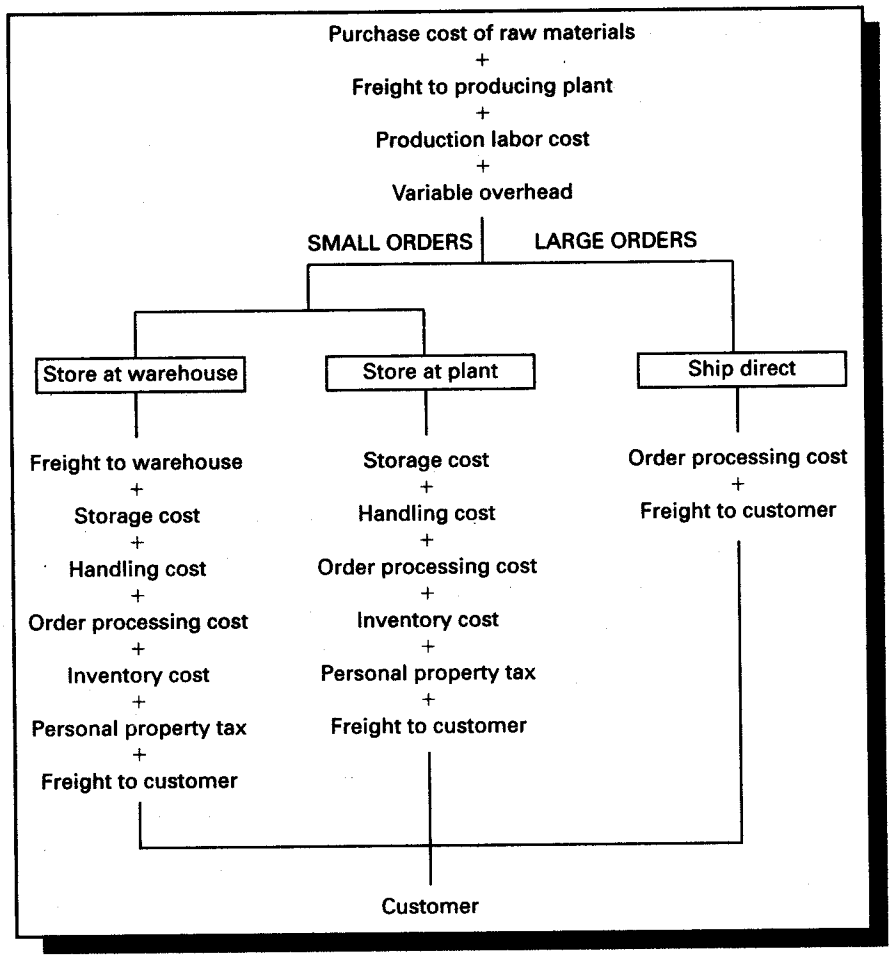

Figure 14-15 Alternative Distribution Channels and Distribution Costs for the Aqua-Chem Company

account for less than five percent of sales and can reasonably be eliminated. This is an application of the 80-20 principle.

Second, those products having similar distribution characteristics may be grouped together and treated as one. For this study, the products were separated into those rated as class 55 and those rated as class 60 by the motor vehicle products classification scheme. These product groups were further separated into those moving through the warehouse network and those moving in volume directly to customers from the plants without the need for storage.

Third, there is little advantage gained by accounting for each customer on an individual basis. Aggregating them by geographic region substantially reduces the computational effort as well as the data collection effort. In this study, 323 demand clusters were chosen, following three-digit zip codes

Finally, mathematical curves were used to estimate the transportation rates between selected points in the network. Little loss in transport rate estimation accuracy was expected because regression curves were fitted to class rates over various distances with coefficients of determination (R^2) of more than 90 percent. Alternatively, the number of individual rates to be obtained for 4 product groups, 6 plants, 22 current and potential warehouses, and 323 demand clusters would have been 170,544. For practical reasons, the latter was rejected.

The Analysis

The major questions for Aqua-Chem were, which plants should be used, and which warehouses should they serve? How many stocking points should be used, and where should they be located? These questions were to be answered in the context of no specific customer service restrictions and the customers paying the warehouse outbound freight costs. A computer model was used to evaluate alternative network configurations. The results of several of the more interesting runs are shown in Table 14-7.

Note first in Table 14-7 that the current production-distribution network has a total cost of $6,348,179, with 63 percent of the demand within 300 miles of a stocking point. Twelve stocking points were being used. Next, an improved benchmark was found. Recall that this is the case where no investment is to be made in the network. Only adjustments to plant and warehouse territories were allowed, closing of facilities was permitted, and service was to remain approximately the same as the benchmark level. The result was an annual savings of $109,669, or 2 percent from the benchmark cost level. Note that warehouse-to-customer transport costs were held constant.

The results from multiple computer runs revealed that the distribution network design was being dictated by production costs at the plant sites. That is, the raw material costs, which were about 80 percent of production costs, were subject to volume discounts due to purchase quantity and shipment size. This resulted in three plants being the optimum number, and they were located at Akron, Asheville, and Dallas (see Table 14-7). A further reduction in the number of plants decreased total production costs, but the savings were more than offset by increased distribution costs. The optimum network design appeared to be three plants with between 12 and 14 stocking points. The three plants were balanced in terms of their capacities to take maximum advantage of purchasing economies. The resulting savings were approximately $188,000, or 3 percent from the benchmark costs. These savings could be achieved with an investment of $11,000 to move some production equipment to the Dallas plant.

Reporting the Financial Results to Management

Addressing the financial concerns of top management involves three key measures: Cash flow, profit, and return on investment. Ideally, the network design changes being proposed increase each of these measures.

needed for planning were discussed. Second, quantitative methods useful in the planning process were outlined. Finally, a logical process was presented using location and simulation methods leading to good network design. This general planning process is used by many management consultants and corporate planners.

QUESTIONS

Some problems in this chapter can be solved or partially solved with the aid of computer software. The software packages in LOGWARE most important for this chapter are MULREG (*MR*), MILES (*D*), SCSIM (*S*), and WARELOCA (*W*). The CD icon will appear with the software package designation where the problem analysis is assisted by one of these software programs. A database may be prepared for the problem if extensive data input is required. Where the problem can be solved without the aid of the computer (by hand), the hand icon is shown. If no icon appears, hand calculation is assumed.

1. Explain what strategic network planning is for a supply chain. Select several companies, manufacturing as well as service oriented, profit versus nonprofit, and outline how you would proceed to design the supply chain network. Discuss the data needed, sources where they might be found, and how you would convert the data to the information needed for analysis. Propose a methodology that you think would be appropriate to the network design problem.
2. Develop a workable list of those members that should be included in a strategic network planning study team to ensure the study's successful completion and implementation.
3. Compute the expected road distance between the following pairs of points using longitude and latitude as the coordinate points.

	Location		Longitude	Latitude
a. From	Lansing, MI	USA	84.55°W	44.73°N
To	Lubbock, TX	USA	101.84°W	33.58°N
b. From	Toronto	CAN	79.23°W	43.39°N
To	Atlanta, GA	USA	84.39°W	33.75°N
c. From	São Paulo	BR	46.37°W	23.32°S
To	Rio de Janeiro	BR	43.15°W	22.54°S
d. From	London	UK	0.10°W	51.30°N
To	Paris	FR	2.20°E	48.52°N

Use a road circuity factor of 1.15.

4. Suppose that a certain linear grid coordinate system has been overlaid on a map of the United States. The grid numbers are calibrated in miles, and there is a road circuity factor of 1.21. Find the expected road distances between the following pairs of points:

	Location	X-Coordinate	Y-Coordinate
a. From	Lansing, MI	924.3	1675.2
To	Lubbock, TX	1488.6	2579.4
b. From	El Paso, TX	1696.3	2769.3
To	Atlanta, GA	624.9	2318.7
c. From	Boston, MA	374.7	1326.6
To	Los Angeles, CA	2365.4	2763.9
d. From	Seattle, WA	2668.8	1900.8
To	Portland, OR	2674.2	2039.7

5. The following table presents a sample of common carrier truck rates in \$/cwt. for shipments in the range of 2000 to 5000 lb, originating at Chicago, with destinations to various cities surrounding Chicago. The rates are taken from the *Rocky Mountain Motor Tariff* and the mileages are from the *Rand McNally Mileage Guide.*

No.	Rate	Miles	No.	Rate	Miles	No.	Rate	Miles
1	4.15	169	21	11.44	1438	41	16.60	2384
2	16.20	2220	22	16.35	3017	42	12.64	1653
3	9.11	1108	23	9.32	962	43	13.85	2272
4	6.81	427	24	10.48	1341	44	3.80	107
5	13.53	2197	25	12.36	1520	45	13.84	1830
6	9.84	1226	26	9.54	1091	46	9.01	929
7	15.28	2685	27	10.94	1390	47	10.94	1455
8	6.92	465	28	9.63	1092	48	10.85	1162
9	9.51	936	29	11.99	1507	49	11.05	1435
10	8.03	751	30	5.95	208	50	15.61	2752
11	7.80	848	31	7.27	581	51	15.93	2866
12	12.77	1923	32	12.79	1694	52	14.18	2376
13	11.28	1004	33	11.30	1469	53	14.88	2018
14	7.80	657	34	11.47	1301	54	16.35	2984
15	8.24	955	35	6.37	315	55	17.81	3128
16	8.40	801	36	17.60	2670	56	16.35	3016
17	13.38	1753	37	8.23	574	57	10.02	1207
18	12.77	1998	38	3.70	109	58	8.00	448
19	10.69	1337	39	16.69	3144	59	12.07	1634
20	8.50	799	40	16.00	1907			

From these data, construct a transport rate estimating curve of the form $R = A + B \times$ distance. Using this curve, what rate would you estimate for a shipment moving 500 miles? How well do you feel that the line accurately represents the rates?

or

6. The California Fruit Growers Association distributes various dried fruit products throughout the country using 24 public warehouses. Estimate the amount of inventory that a new warehouse would have if the annual sales through the warehouse were known. The company has collected the following data from their 24 warehouses:

No.	Annual Warehouse Throughput, $	Average Inventory Level, $	No.	Annual Warehouse Throughput, $	Average Inventory Level, $
1	21,136,032	2,217,790	13	6,812,207	1,241,921
2	16,174,988	2,196,364	14	28,368,270	3,473,799
3	78,559,012	9,510,027	15	28,356,369	4,166,288
4	17,102,486	2,085,246	16	48,697,015	5,449,058
5	88,228,672	11,443,489	17	47,412,142	5,412,573
6	40,884,400	5,293,539	18	25,832,337	3,599,421
7	43,105,917	6,542,079	19	75,266,622	7,523,846
8	47,136,632	5,722,640	20	6,403,349	1,009,402
9	24,745,328	2,641,138	21	2,586,217	504,355
10	57,789,509	6,403,076	22	44,503,623	2,580,183
11	16,483,970	1,991,016	23	22,617,380	3,001,390
12	26,368,290	2,719,330	24	4,230,491	796,669

Construct an inventory-throughput curve for these warehouses. If a warehouse has an annual throughput of $50,000,000, how much inventory would you estimate for this warehouse? What comments can you make about warehouse 22? Explain how this relationship might be used in network planning. Recall that you may have already constructed this curve in a problem in Chapter 9.

7. Several broad classes of model types are available to assist in network analysis. Identify and contrast them. Suggest the circumstances under which each might be an appropriate choice.
8. The expert system is a new approach to solving complex problems. The expert system is based on the way that humans solve problems as expressed by a set of IF-THEN statements. As if you were to explain to someone how to locate a warehouse, develop at least 10 IF-THEN statements that would guide him or her to good locational choices. For example, a statement might be "If one warehouse is to be located, then a good location is likely to be in the center of the demand being served by the warehouse."
9. What is the usefulness of each of the following in the methodology for finding the best network design?
   a. Benchmarking
   b. Improved benchmark
   c. Maximum opportunity design
   d. What-if analysis
10. Explain how the strategic design of the network may favorably or unfavorably affect the efficiency and effectiveness of the supply channel to operate on a routine basis.
11. Sealy is the largest manufacturer of mattresses in the United States, having the largest market share. The company focuses on the higher-quality, higher-priced

market segment. Sealy manufactures to order and, therefore, it carries no finished goods inventory. Shipment to retailers takes a day or two. The vice president of manufacturing services is concerned that Sealy's raw materials inventories are too high. These raw materials consist of (1) wire for springs, (2) foam rubber for padding, (3) wood for framing, and (4) ticking, or covering material. There are currently 20 plants located throughout the United States.

How would you propose to approach her problem?

CASE STUDIES

Usemore Soap Company:

A Warehouse Location Case Study

The Usemore Soap Company produces a line of cleaning compounds, used mainly for industrial and institutional purposes. Typical products include general cleaning compounds, dishwasher powders, rinse agents, hand soaps, motor vehicle washing compounds, and cleaning products for the food industry. The product line is composed of more than 200 products and nearly 800 individual product items. Package sizes range from 18-pound cases to large metal drums weighing 550 pounds.

Sales are generated throughout the 48 contiguous United States, with additional sales in Hawaii, Alaska, and Puerto Rico. Customers typically purchase in quantities less than 10,000 pounds, that is, less-than-truckload (LTL) quantities. A few customers purchase in truckload and bulk quantities. Annual LTL sales, which pass through the warehouses, are running at the 150 million pound level. Volume sales, which are served directly from plants, add another 75 million pounds. These sales represent approximately $160 million in revenue.

The primary marketing effort comes from a direct selling force operating under the incentive of a liberal sales commission structure. Salespeople look upon themselves as individual entrepreneurs and have a great deal of autonomy within the company. This marketing strategy has generally proved successful for the company, as the company has often been referred to as one of the most profitable divisions within its widely diversified parent organization.

In spite of the high profitability, company management is concerned about the costs of producing and distributing the product line to maintain its competitive edge. Growth and shifting demand patterns are straining the production capacity of the four existing plants. In addition, changing costs of distribution, as well as the fact that the distribution network has not been studied in 12 years, raise questions about the proper placement of the warehouses. What follows is a summary of the problem conditions being faced by management. You are to suggest an improved distribution network that meets the stated customer service policy and minimizes total network production-distribution costs.

BACKGROUND

The current distribution network consists of four full product line plants located at Covington, Kentucky, New York, New York, Arlington, Texas, and Long Beach, California. The plants are currently producing product for their low-volume customers at the level of 595,102 cwt.,[1]

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[1] cwt. = 100 pounds

Table 1
Current Plant and Public Warehouse Locations

No.	Location	No.	Location	No.	Location
1	Covington, KY[a]	9	Cleveland, OH	17	Milwaukee, WI
2	New York, NY[a]	10	Davenport, IA	18	Orlando, FL
3	Arlington, TX[a]	11	Detroit, MI	19	Pittsburgh, PA
4	Long Beach, CA[a]	12	Grand Rapids, MI	20	Portland, OR
5	Atlanta, GA	13	Greensboro, NC	21	W Sacramento, CA
6	Boston, MA	14	Kansas City, KS	22	W Chester, PA
7	Buffalo, NY	15	Baltimore, MD		
8	Chicago, IL	16	Memphis, TN		

[a] Field warehousing as part of plant operations.

390,876 cwt., 249,662 cwt., and 241,386 cwt., respectively. This output is shipped from plants either to field warehouses in the distribution network or to customers within the local areas of the plants. In the latter case, plants serve as field warehouses as well as producing centers.

Warehousing takes place at 18 public warehouses and at the four plant locations, as shown in Table 1. These warehouses are dispersed in such a fashion that the majority of the customers are within a one-day delivery time frame of a stocking point; that is, approximately 300 miles. Except for the plants serving as warehouses, the warehouses are supplied in full truckload quantities. Less-than-truckload shipments serve customers. Customer order processing takes place at each warehouse location.

In addition, two potential plant sites are being considered at Chicago, Illinois, and Memphis, Tennessee. Additional warehouse sites are considered at the locations shown in Table 2.

Potential warehouse sites are made based on sales personnel's suggestions, favorable warehousing rates, good warehousing service availability, proximity to demand concentrations, and filling out of the distribution network. Of the existing and potential warehouse sites, it is hoped that an improved mix of warehouses can be found. In addition, plant expansion, either at existing sites or at new sites, will be needed to meet future demand projections. Specifically, answers to the following questions are sought:

1. How many warehouses should be operated now and in the future?

Table 2
Possible Public Warehouse Locations

No.	Location	No.	Location	No.	Location
23	Albuquerque, NM	32	Phoenix, AZ	41	Louisville, KY
24	Billings, MT	33	Richmond, VA	42	Columbus, OH
25	Denver, CO	34	St Louis, MO	43	New York, NY
26	El Paso, TX	35	Salt Lake City, UT	44	Hartford, CT
27	Camp Hill PA	36	San Antonio, TX	45	Miami, FL
28	Houston TX	37	Seattle, WA	46	Mobile, AL
29	Las Vegas NV	38	Spokane, WA	47	Memphis, TN P[a]
30	Minneapolis MN	39	San Francisco, CA	48	Chicago, IL P[a]
31	New Orleans LA	40	Indianapolis, IN		

[a] Prefers to warehouses at additional plant sites.

2. Where should they be located?
3. Which customers and associated demand should be assigned to each warehouse and plant?
4. Which warehouses should be supplied from each plant?
5. Should production capacity be expanded? When, where, and by how much?
6. What level of customer service should be provided?

SALES DATA

Manufacturing of soap liquids and powders is an uncomplicated and easily duplicated process, which contributes to substantial competition in the marketplace. The undifferentiated nature of soap products results in keen competition in both price and service. Customer service is of particular concern because it is directly affected by the choice of warehouses. No specific dollar figure can be placed on the total value of good distribution service, as it depends on customer attitudes about service and resulting patronage. The general feeling in the company is that service should be maintained at a high level so as not to jeopardize sales. A "high" level of service is taken to mean delivery time of 24 to 48 hours or less. This generally places customers somewhere between 300 and 600 miles of warehouses.

Annual sales for the products that move through the warehousing network are 147 million pounds for annual revenue of slightly more than $100 million. Sales are distributed similarly to population centers with an average profit margin of 20 percent. Figure 1 shows the six major sales territories, with sales volume in pounds by state. The company has more than 70,000 individual customer accounts, and these are aggregated into 191 active demand centers. A demand center is a grouping of zip code areas into a zip sectional center as the focus of the collected demand. These demand centers, along with how they are currently being served, are given in Table 3. In addition, the sales territory in which the demand center is grouped is shown.

The five-year plan shows volume growth throughout the United States. This growth will not be uniform due to population and business migration patterns, competition, and varying promotional efforts. The changes in volume compared with current volume levels are projected by sales territory as follows:

Region No.	Sales Territory	Five-Year Growth Factor[a]
1	Northeast	1.30
2	Southeast	1.45
3	Midwest	1.25
4	Northwest	1.20
5	Southwest	1.15
6	West	1.35

[a] Multipliers to the current sales volume.

PRODUCTION COSTS AND CAPACITIES

The production variable costs at existing plants vary by location. This variance results from labor rate differences, volume purchases of raw materials, and inbound transport cost differences due to the proximity of the plants to major raw materials sources. These costs are listed next.

Plant	Variable Production Cost
Covington, KY	$21.0
New York, NY	19.9
Arlington, TX	21.6
Long Beach, CA	21.1

The potential plant at Chicago has an estimated cost of $21.0 per cwt.; and the Memphis plant has a cost of $20.6 per cwt. Expansion at any existing plant site would have the current variable cost. Fixed costs are not included for existing plants because these are sunk costs. However, to construct a new plant or expand an existing one would cost a minimum of

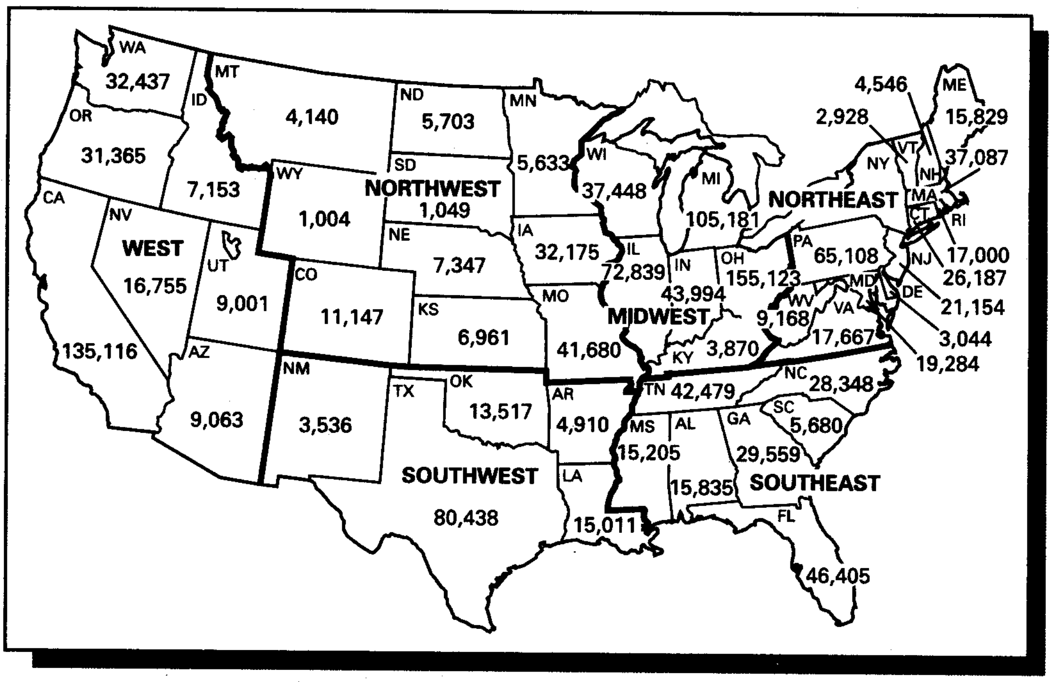

Figure 1 Usemore Soap Company Annual Sales in Cwt. by State, with Major Sales Districts Defined

$4 million. This cost would result in an output for the plant (or an output increase in the case of a plant addition) of up to 1 million cwt. per year for the near future.

According to current distribution patterns, the existing plants are producing, relative to throughput capacity (in cwt.), at the following rates:

Plant	Current Capacity	Current Production	Percent of Capacity
Covington, KY	620,000 cwt.	595,102 cwt.	96%
New York, NY	430,000	390,876	91
Arlington, TX	300,000	249,662	83
Long Beach, CA	280,000	241,386	86%
Total	1,630,000	1,477,026	91

WAREHOUSING RATES AND CAPACITIES

Company contracts with public warehousemen show that rates are categorized as storage, handling, and accessorial. Storage rates are quoted on a $/cwt./month basis of average inventory held. Handling charges are incurred whenever in or out movement of the product occurs and are assessed on a $/cwt. basis. Accessorial charges are for a number of services, such as bill of lading preparation, local delivery, and stock status reporting. Similar charges are estimated for the four plant warehouses as a fair share of production operations.

Also associated with warehousing are the stock replenishment costs. These are costs for preparing the paperwork for normal replenishment and the expediting of stock into the warehouse. Stock order costs as well as customer order costs are computed by multiplying the average cost per order by the average number of orders for the warehouse.

The warehouse-related costs and other associated information are given in Table 3. Costs for existing points are taken from company records. Those for potential warehouses are determined from quotas by warehousemen in the appropriate cities. Estimates are made of costs where such information is not otherwise available.

There are no effective capacity limits on public warehousing. Usemore's space need is a small fraction of a public warehouseman's total capacity. On the other hand, a throughput of at least 10,400 cwt. per year, or a replenishment truckload every two weeks, is the desired minimum throughput needed to open a warehouse. Available space is limited at the four current plant sites. The stocking limits in terms of throughput at Covington = 450,000 cwt., New York = 380,000 cwt., Arlington = 140,000 cwt., and Long Beach = 180,000 cwt.

TRANSPORTATION COSTS

Three general transportation cost types are important to Usemore: inbound, outbound, and local delivery transport charges. Inbound transportation costs to a warehouse depend on the volume shipped and the distance between plant and warehouse. A sampling of truck common carrier rates at various distances from the plants for full truckload shipments shows that the transport rate between a plant and warehouse (P-W) can be reasonably approximated by a linear function. That is, the truckload rate is

$$\text{P-W rate (\$/cwt.)} = 0.92 + 0.0034d \text{ (miles)}$$

where *d* is the distance between the two points.[2] Total inbound transport costs are determined by multiplying the P-W rate by the volume assigned to flow between the plant and warehouse.

Warehouse outbound transport costs depend on the distance that a customer is from the warehouse. If the customer is roughly within 30 miles of the warehouse, local cartage rates generally apply. These local delivery rates are shown by warehouse in Table 3. For distances greater than 30 miles, a linear function similar to that for the inbound rates can be developed. Given the average shipment size from the warehouses of approximately 1,000 pounds, the warehouse to customer (W-C) rate function is

$$\text{W-C rate (\$/cwt.)} = 5.45 + 0.0037d$$

Computation of total warehouse outbound transport costs is carried out in the same manner as for inbound transport costs.

INVENTORY COSTS

Inventory costs depend on the average inventory maintained at a warehouse and the inventory rate factors that apply to the inventory level. These rate factors include the cost of capital, personal property taxes, and insurance costs. The average inventory at a warehouse will vary by the demand on the warehouse and by the method used to control the inventory. A mathematical function to express inventory based on annual warehouse throughput is found by plotting the annual average inventory against annual throughput at each active stocking point. The resulting curve is shown in Figure 2. Knowing that the annual cost-to-carry-inventory rate is approximately 12 percent of the average product value of $26 per cwt., the total cost to carry inventory at each warehouse is given by

$$IC_i = (0.12)(26)(11.3D_i^{0.58}) = 35.3D_i^{0.58}$$

where

IC_i = annual inventory carrying cost at warehouse i (\$)
D_i = annual demand throughput at warehouse i (cwt.)

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[2] For simplicity, one aggregated relationship is shown. In practice, several such relationships would be used to reflect the rate difference caused by geographic locations of the shipment origin points.

Table 3 Stocking Point Rate and Order Size Information

WHSE NO.	STORAGE ($/$)^a	HANDLING ($/CWT.)^b	STOCK ORDER PROCESSING ($/ORDER)	STOCK ORDER SIZE (CWT./ORDER)	CUSTOMER ORDER PROCESSING ($/ORDER)	CUSTOMER ORDER SIZE (CWT./ORDER)	LOCAL DELIVERY RATE^c ($/CWT.)
1	0.0672	0.46	18	400	1.79	9.05	1.90
2	0.0567	0.54	18	400	1.74	10.92	3.89
3	0.0755	0.38	18	400	2.71	11.59	2.02
4	0.0735	0.59	18	400	1.74	11.30	4.31
5	0.0946	0.50	18	401	0.83	9.31	1.89
6	0.1802	0.75	18	405	3.21	9.00	4.70
7	0.0946	0.74	18	405	1.23	8.37	1.55
8	0.2072	1.14	18	405	1.83	13.46	1.79
9	0.1802	1.62	18	409	4.83	9.69	4.92
10	0.1442	1.14	18	410	2.74	8.28	2.23
11	0.0946	1.04	18	409	3.93	10.20	1.81
12	0.1982	1.06	18	410	3.18	15.00	1.00
13	0.0766	1.06	18	400	1.08	9.07	1.63
14	0.1262	1.22	18	423	1.56	11.72	1.17
15	0.1126	0.82	18	426	1.20	9.35	1.73
16	0.0991	0.64	18	433	1.78	8.70	0.50
17	0.1577	0.71	18	394	5.33	8.07	1.46
18	0.1307	0.79	18	398	0.91	7.66	2.29
19	0.1487	1.15	18	399	2.08	9.39	2.20
20	0.2253	0.80	18	490	1.10	7.31	1.49
21	0.1370	1.39	18	655	1.70	9.31	2.72
22	0.0991	0.83	18	400	2.46	10.14	4.17
23	0.1260	0.59	18	110	2.33	5.07	2.37
24	0.0631	0.45	18	134	1.88	6.80	1.36
25	0.0946	1.68	18	341	2.58	6.83	2.21
26	0.1216	0.88	18	149	1.83	14.32	0.80
27	0.0721	0.55	18	198	1.83	7.38	3.88
28	0.1532	0.80	18	420	1.58	9.70	2.14
29	0.1172	1.04	18	287	0.78	7.52	1.51
30	0.1080	1.46	18	408	5.33	11.46	1.70
31	0.1487	0.95	18	340	1.36	10.48	1.63
32	0.1396	0.69	18	333	1.50	6.67	1.66
33	0.1126	0.64	18	277	2.33	11.98	1.54
34	0.1712	1.35	18	398	0.93	10.13	1.84
35	0.1261	0.79	18	434	2.08	6.81	1.58
36	0.1352	0.80	18	323	0.88	7.67	1.93
37	0.2704	0.96	18	423	0.89	8.57	3.08
38	0.2250	0.80	18	425	2.88	7.61	1.43
39	0.1487	1.49	18	400	1.46	7.55	6.44
40	0.2073	1.14	18	400	2.75	10.13	2.83

Whse no.	Storage ($/$)[a]	Handling ($/cwt.)[b]	Stock order processing ($/order)	Stock order size (cwt./order)	Customer order processing ($/order)	Customer order size (cwt./order)	Local delivery rate[c] ($/cwt.)
41	0.2073	1.14	18	400	2.75	10.13	2.83
42	0.1802	1.62	18	400	2.75	10.13	4.81
43	0.2613	1.39	18	400	2.71	11.59	3.89
44	0.1396	0.71	18	400	2.04	9.37	3.89
45	0.1036	0.55	18	400	2.75	10.13	1.74
46	0.0946	0.55	18	400	1.74	9.31	1.89
47	0.0682	0.64	18	400	1.78	8.70	0.50
48	0.0682	1.22	18	400	1.79	9.05	1.55

[a] Annual rate in $ per $ of average inventory in the warehouse.

[b] Annualized rate for moving 1 cwt. in and out of the warehouse.

[c] A transport rate that applies to customer shipments within 30 miles of a stocking point.

WAREHOUSE OPERATING COSTS

Warehouse operating costs refer to the combination of storage and handling costs incurred resulting from assigning demand to warehouses. Storage costs are computed by taking the storage rate and multiplying it by an estimate of the average inventory in the warehouse. Mathematically, this can be expressed as

$$SC_i = SR_i(26)(11.3D_i^{0.58})$$

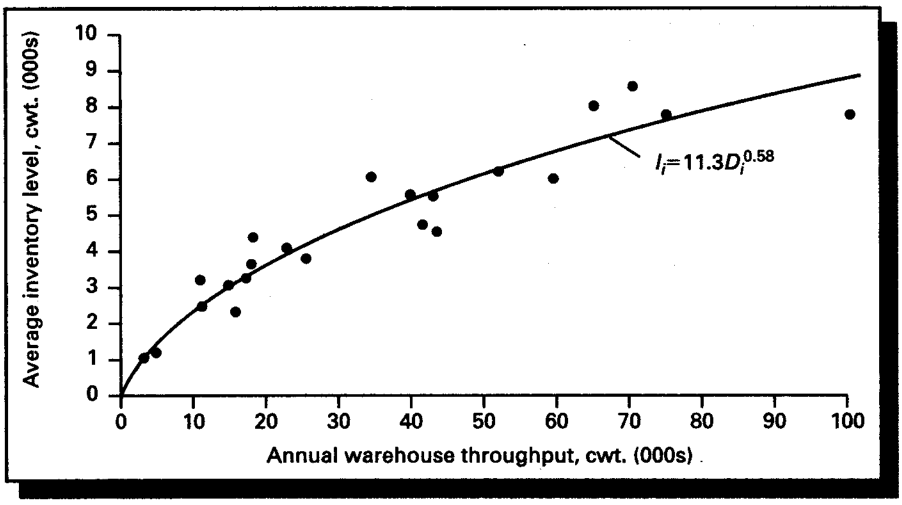
where

SC_i = annual cost of stock storage at warehouse i ($)

SR_i = storage rate from warehouse i from Table 4

D_i = annual demand throughput at warehouse i (cwt.)

Figure 2 The Inventory-to-Warehouse Throughput Relationship for the Usemore Soap Company



Warehouse to Customer Distance	Percent of Demand	Cumulative Percent of Demand	Total Demand (cwt.)
0–100 mi.	56.4%	56.4%	833,043
101–200	21.3	77.7	314,607
201–300	15.7	93.4	231,893
301–400	2.1	95.5	31,018
401–500	1.5	97.0	22,155
501–600	0.5	97.5	7,385
601–700	2.0	99.5	29,541
701–800	0.5	100.0	7,384
801–900	0.0	100.0	0
901–1000	0.0	100.0	0
> 1000	0.0	100.0	0
	100.0%		1,477,026

Table 4 Benchmark Customer Service Profile

Handling costs are strictly a function of the warehouse throughput. They are determined by the handling rate multiplied by the throughput, or

$$HC_i = (HR_i)D_i$$

where

HC_i = annual handling cost at warehouse i ($)

HR_i = handling rate at warehouse i from Table 4

ORDER-PROCESSING COSTS

Order-processing costs refer to the charges incurred in handling the paperwork associated with stock replenishment and customer orders. Both types of costs are computed for each warehouse in essentially the same way. That is, the order-processing rate is multiplied by the annual demand on the warehouse and the result divided by the order size.

TOTAL COSTS

The total costs for various production distribution configurations can be determined by summing all the relevant costs. For the Usemore Soap Company, these are production costs; warehouse operating costs (storage, handling, stock order processing, and customer order processing); transportation costs (warehouse inbound, outbound, and local delivery); and inventory-carrying costs. Changing the number and location of plants and warehouses will cause a change in the balance of these cost factors. For example, adding warehouses will typically reduce transportation costs but increase inventory costs, as well as affect customer service. Assessing the trade-offs between costs and customer service is at the heart of this problem type.

The cost and customer service summaries for the current network design are shown in Tables 4 and 5. At present, Usemore Soap is able to place 93 percent of its demand within 300 miles of warehouses for a total annual cost of $42,112,463.

A COMPUTER-ASSISTED ANALYSIS

Although enough data have been provided to carry out an analysis manually, a computer program (WARELOCA, a module in LOGWARE) accompanies this case study. Given a particular combination of plants, plant capacities,

Table 5
Cost Profile for the Current Distribution Network

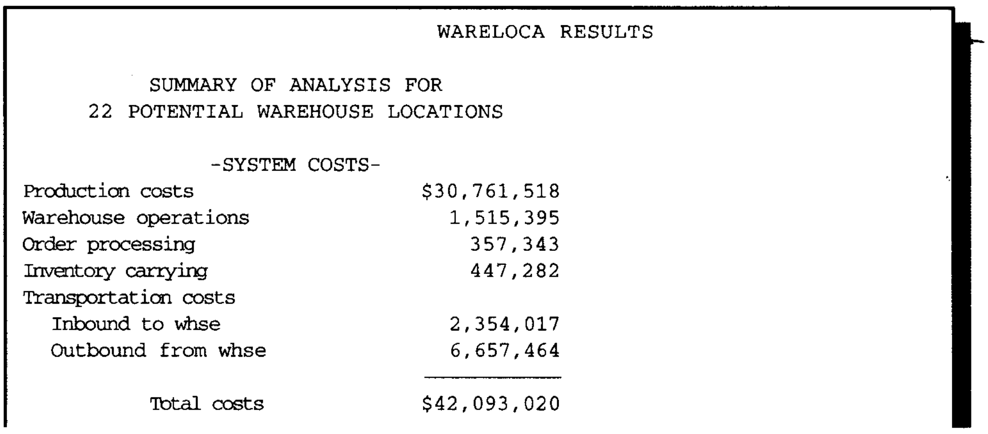
Cost Category	Cost
Production	$30,761,520
Warehouse operations	1,578,379
Order processing	369,027
Inventory carrying	457,290
Transportation:	
Inbound to warehouse	2,050,367
Outbound from warehouse	6,895,880
Total cost	$42,112,463

customer service constraints, and warehouses, the program optimally assigns demand centers to warehouses and warehouses to plants by means of linear programming. From the selected list of warehouses, the least expensive will be chosen if more than one choice is available within the prescribed service distance from a demand center. If a warehouse cannot be found within the service distance, the warehouse closest to the demand center will be selected.

Only linear variable costs are used in the allocation of demand centers to warehouses. Storage and capital costs, which are nonlinear, are not used in the allocation process. They are included in the system costs for a particular configuration. Fixed costs are neither included in the allocation, nor are they shown in the total system costs. They must be externally added to system costs.

WARELOCA is a program in which you provide the plant locations and capacities, warehouse locations, customer service distance, and demand and cost levels. Each run of the program represents an evaluation of a particular network configuration. The results of a sample WARELOCA run in which the current network is *approximated*[3] (not the true benchmark) where the existing 4 plants and 22 warehouses are evaluated are given in Figure 3. ■

Figure 3 WARELOCA Results for an Approximated Benchmark Run



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                              WARELOCA RESULTS

          SUMMARY OF ANALYSIS FOR
      22 POTENTIAL WAREHOUSE LOCATIONS

                -SYSTEM COSTS-
Production costs                $30,761,518
Warehouse operations              1,515,395
Order processing                    357,343
Inventory carrying                  447,282
Transportation costs
  Inbound to whse                 2,354,017
  Outbound from whse              6,657,464
                                -----------
         Total costs            $42,093,020
```

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[3] Plant capacities are set at current production levels, customer service set at 300 miles, and the current 22 warehouses are selected for evaluation.

Figure 3 (*cont.*)

```
                     CUSTOMER SERVICE PROFILE FOR A DESIRED
                           SERVICE DISTANCE OF 300 MILES
Distance from whse          Percent of      Distance from whse          Percent of
to customer (miles)         demand          to customer (miles)         demand
  0    to   100               55.9            800    to     900                .0
 100   to   200               18.2            900    to   1,000                .0
 200   to   300               19.5          1,000    to   1,500                .0
 300   to   400                1.8          1,500    to   2,000                .0
 400   to   500                2.0          2,000    to   2,500                .0
 500   to   600                 .3          2,500    to   3,000                .0
 600   to   700                2.0                   >    3,000                .0
 700   to   800                 .4                                          -----
                                                                   Total  100.0


                    -PLANT THRUPUT AND COSTS-
Location              Thruput (cwt)          Production costs
COVINGTON KY            595,102                 12,497,142
NEW YORK NY             390,876                  7,778,432
ARLINGTON TX            249,662                  5,392,699
LONG BEACH CA           241,386                  5,093,244
MEMPHIS TN                    0                          0
CHICAGO IL                    0                          0
                      ---------                 ----------
Totals                1,477,026                 30,761,518

                              -WAREHOUSE THRUPUT AND COSTS-
Whse                          Thruput     Whse
no.    Location               (cwt)       Total, $      Storage       Handling       Capital
  1    COVINGTON KY P         236,640     180,853        25,845        108,854        46,153
  2    NEW YORK NY P          228,067     189,677        21,345        123,156        45,176
  3    ARLINGTON TX P         104,081      86,246        18,033         39,550        28,662
  4    LONG BEACH CA P        106,047     109,288        17,747         62,567        28,974
  5    ATLANTA GA              46,949      55,775        14,239         23,474        18,062
  6    BOSTON MA               49,350      83,524        27,919         37,012        18,592
  7    BUFFALO NY              28,342      45,076        10,625         20,973        13,478
  8    CHICAGO IL              87,860     170,997        44,858        100,160        25,979
  9    CLEVELAND OH                 0           0             0              0             0
 10    DAVENPORT IA            13,068      33,837        10,337         14,897         8,602
 11    DETROIT MI              82,999     131,269        19,815         86,318        25,135
 12    GRD RAPIDS MI           17,330      45,238        16,736         18,369        10,132
 13    GREENSBORO NC           31,832      57,362         9,203         33,741        14,417
 14    KANSAS CITY KS          73,416     137,595        24,618         89,567        23,409
 15    BALTIMORE MD            38,128      62,294        15,021         31,264        16,008
 16    MEMPHIS TN              67,480      83,888        18,409         43,187        22,292
 17    MILWAUKEE WI            28,121      51,015        17,632         19,965        13,417
 18    ORLANDO FL              44,523      71,765        19,076         35,173        17,515
 19    PITTSBURGH PA           21,553      50,534        14,249         24,785        11,499
 20    PORTLAND OR             74,280     127,242        44,250         59,424        23,568
 21    W SACRAMENTO CA         65,744     137,256        23,915         91,384        21,957
 22    W CHESTER PA            31,216      51,936        11,772         25,909        14,255
                            ---------   ---------     ---------      ---------     ---------
       Totals               1,477,026   1,962,667       425,655      1,089,739       447,282
```

			Transport costs	
Whse no	Location	Order processing	Inbound	Outbound
1	COVINGTON KY P	57,453	0	1,166,502
2	NEW YORK NY P	46,603	210,610	1,135,465
3	ARLINGTON TX P	29,020	96,128	511,022
4	LONG BEACH CA P	21,101	97,942	528,650
5	ATLANTA GA	6,293	112,810	212,015
6	BOSTON MA	19,794	82,324	261,289
7	BUFFALO NY	5,424	59,064	72,647
8	CHICAGO IL	15,850	168,091	276,774
9	CLEVELAND OH	0	0	0
10	DAVENPORT IA	4,898	30,896	74,424
11	DETROIT MI	35,631	154,332	173,983
12	GRD RAPIDS MI	4,434	34,705	46,545
13	GREENSBORO NC	5,222	71,933	129,723
14	KANSAS CITY KS	12,896	196,711	381,234
15	BALTIMORE MD	6,504	60,638	152,684
16	MEMPHIS TN	16,611	174,640	344,308
17	MILWAUKEE WI	19,857	62,954	42,548
18	ORLANDO FL	7,302	174,726	236,580
19	PITTSBURGH PA	5,746	45,302	47,416
20	PORTLAND OR	13,906	325,989	343,276
21	W SACRAMENTO CA	13,811	153,326	379,100
22	W CHESTER PA	8,977	40,887	141,269
	Totals	357,343	2,354,017	6,657,465

Essen USA

Essen is a German candy company that produces and distributes chocolate and other types of candies throughout Europe and the United States. For the U.S. market, the candies are manufactured in Essen, Germany, and shipped through the port at Amsterdam in the Netherlands. The product enters the United States through a port in New Jersey and is stored in a warehouse in Edison, New Jersey. From this central warehouse, the product is redistributed to the warehouses (there are many of these) of the purchasing companies that in turn ship it to their retail outlets (there are many of these). These buyers typically are large retailers such as Wal-Mart, Walgreens, and Giant Eagle, as well as many small retailers that purchase through distributors. Essen's supply channel is shown in Figure 1. Essen's distribution cost and customer service are affected by the product flow throughout the entire supply chain. Although Essen directly controls only a portion of the supply chain, good planning of the entire supply chain may benefit Essen, its buyers, and, ultimately, the customers. Essen may be able to influence its customers through price-quantity discounts and other incentives, if it can estimate the effect that these might have on its downstream channel members.

SALES

Essen had annual sales to its customers (level 2) of about $80 million in the United States on 36 million pounds of candies. Sales at retail (level 1)

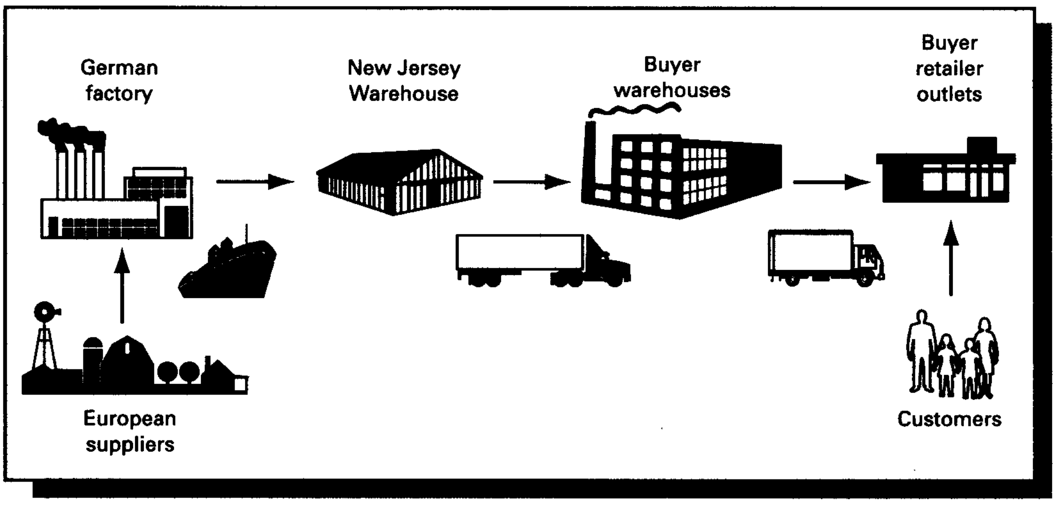

Figure 1 The Supply Channel for Essen

were about $104 million. This is an average price of $2.22 per lb to Essen's customers, who then add a 30 percent markup for an average price to end customers of $2.89 per lb. Sampling of sales data shows that daily sales average 100 thousand lb with a standard deviation of 15 thousand lb. Sales vary according to a normal distribution pattern. There is some increase in customer demand around holiday periods (Valentine's Day, Easter, Thanksgiving, and Christmas) with less-than-average sales in the fall and winter months. Summer months have slightly below average sales. Typical seasonal indices are as follows:

Month	Index	Month	Index	Month	Index	Month	Index
Jan	0.25	Apr	0.75	Jly	0.75	Oct	0.75
Feb	1.25	May	0.75	Aug	0.75	Nov	1.50
Mar	1.25	Jun	0.75	Sep	0.75	Dec	2.50

Sales growth has been modest at about 1 percent per year.

RETAILER OUTLETS/LEVEL 1

The retailers (level 1) in the channel restock their shelves on a weekly basis. Demand is forecasted from sales by averaging the last seven days of sales (seven-day moving average). The inventory-control policy is to stock to demand. That is, the amount of stock on the shelves is reviewed every seven days and a target inventory level of ten days sales is used for control purposes. Ten days of demand is determined from the frequency for reviewing stock levels, the risk of running out, and the experience in providing adequate stock levels.

The approximate worth of 1,000 lb of product in inventory is $2,220. Inventory-carrying cost is nominally set at 25 percent of item value per year. The cost for filling customer orders is the result of dividing store overhead and labor by the units sold. For a single product line such as candy, it is no more than $1 per 1,000 lb. On the other hand, the retailer purchase order preparation cost includes form completion, order transmission, and miscellaneous checking. A cost of $35 per order is reasonable.

Time to fill a customer request for candy is nominally set at the minimum time of one day with no variation. This accounts for the time that the customer drives to the store, selects the product, checks out, and drives home.

A product such as this is generally not back ordered when an out-of-stock situation occurs. Sales are lost instead. Therefore, product is stocked at a high fill rate (98%). Back order costs are set at 0.67 per thousand lb to represent the lost sales effect.[1]

WAREHOUSES/LEVEL 2

Essen supplies to a number of its customers' warehouses. It is typical for these warehouses to forecast the volume of activity on them based on a 30-day moving average. Inventory levels are usually reviewed every 30 days and a target level of 45-days sales is used to replenish inventories. A fill rate of 95 percent is desired.

The cost to fill a retailer's order from warehouse stocks is estimated to be $20 per 1,000 lb, which includes some stock checking, credit checking, information transmission, and some overhead charges. Retailer store orders can be processed in two days with a standard deviation of 0.2 days. The cost to prepare and transmit the purchase orders for warehouse stock replenishment is $75 per order.

Inventory carrying cost is 25 percent of inventory value, which is estimated to be $2,220 per 1,000 lb. Orders that cannot be filled from available stock are back ordered at a cost of $100 per 1,000 lb.

ESSEN'S NEW JERSEY WAREHOUSE/LEVEL 3

The warehouse at New Jersey is the importation and redistribution point for Essen's products in the United States. It ships the full line of candy products to all its customers' warehouses from here. Overall requirements are forecasted using a 360-day moving average, even though there is a significant seasonal pattern in sales around the end of the calendar year. Inventory is planned on an aggregate basis (all products combined) with a stock-to-demand type of policy. Inventory review and forecasting take place every 30 days and a target quantity is 90-days sales. Rather high inventory levels are held because of the need for good stock availability to customers and the long lead times resulting from the distant supply source. One thousand pounds of product held in inventory is valued at $1,710 at cost. The company uses a 20 percent annual inventory-carrying charge. An in-stock probability (fill rate) of 95 percent is desired. Essen's customer order size averages 5,000 lb.

Preparing a purchase order on the factory is estimated to average $75 per order. The cost to process a buyer's order is $15 per 1,000 lb. The time to fill a distributor's order is three days, with a standard deviation of 0.3 days. All unfilled customer orders are back ordered at an estimated cost for the extra handling of $25 per 1,000 lb.

FACTORY/SOURCE

The factory purchases in Europe the materials for candy products at an average cost of U.S. $1,000 per 1,000 lb. The average lot size across all product line items is 10,000 lb. Production cost including overhead is about $850 per 1,000 lb. The time for production from when an order is received, reviewed, held for best time in the production schedule, and processed is eight days, with a standard deviation of two days. However, if larger batch sizes of 20,000 lb are produced, production cost can be reduced to $825 per 1,000 lb. Then production time is lengthened to 10 days, with a standard deviation of 2.1 days.

The cost for filling a warehouse order, mainly preparing the order for shipment, is $10 per 1,000 lb.

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[1] This is the estimated profit earned on a lb of product, or $2.89 – 2.22 = $0.67 per lb.

Administrative organization is the structure that facilitates the creation, the implementation, and the evaluation of plans. It is the formal or informal mechanism for allocating the firm's human resources to achieve its goals. The organization may appear as a formalized chart of functional relationships, an invisible set of relationships understood by the firm's members but not stated in any formal way, or a combination of these. Whichever is the case, attempting to establish human relationships in an optimal way is probably the firm's most difficult task. No precise algorithms exist for doing this. The best we can hope for are some guidelines that may be useful in establishing acceptable organizational structures.

The focus of this chapter is specifically on the organizational structure required for the management of the business logistics function. The discussion is separated into four parts. First is organizing the logistics effort. Concern here is with *why* a logistics/SC organization is needed. Second are the choices that management has available. These range from formal to informal organization forms, as well as the placement of the organizational form within the company's organization structure. The third concerns the management of logistics across different organizations. Finally, we will look at the alternatives to the organizational structure that have the purpose of operating a supply channel, namely, outsourcing some or all of the logistics effort through strategic logistics/SC alliances, logistics/SC partnerships, logistics/SC third-party providers, and collaborative arrangements.

ORGANIZING THE LOGISTICS/SC EFFORT

Positioning those persons in the firm who are responsible for logistics activities in a way that encourages coordination among them is the major problem of logistics/SC organization. Such organizational arrangements promote efficiency in the supply and distribution of goods and services by encouraging the cost trade-offs that are frequently encountered in planning and operating the logistics system.

Need for Organization Structure

Logistics/SC is a vital activity that must be carried out by virtually every type of firm or institution. This means that some organizational arrangement, whether formal or informal, will have been made to handle product and service movement. What then is the need for any specific consideration of organization structure?

Organizational Fragmentation

A traditional form of organization that many have adopted is the grouping of their activities around the three primary functions of finance, operations, and marketing, as

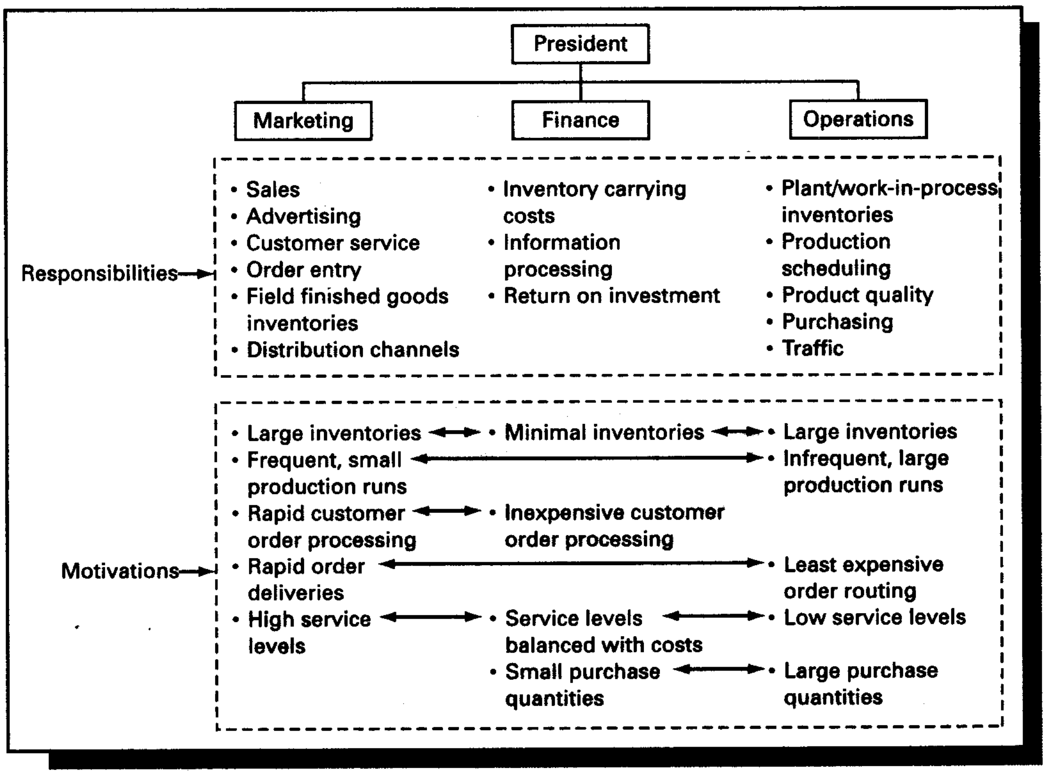

Figure 15-1 Organization of a Typical Manufacturing Firm with Reference to Logistics/SC Activities

shown in Figure 15-1. From a logistics point of view, this arrangement has resulted in a fragmentation of the logistics activities among these three functions whose primary purposes are somewhat different from those of logistics. That is, responsibility for transportation might be placed under operations, inventory divided among the three functions, and order processing placed under either marketing or finance. Yet marketing's primary responsibility may be to maximize revenue, operations' responsibility may be to produce at the lowest per-unit cost, and finance's responsibility may be to minimize the capital costs or maximize return on investment for the firm. These motivational cross-purposes led one executive some years ago to wisely observe:

> If permitted to run free, a salesman and his manager would promise his customer impossible delivery service from a plant or distribution center. On the other hand, the production manager, if permitted, would request that all orders be accumulated for long periods to reduce the cost of setups, and allow more time to plan economic materials procurement quantities.[2]

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[2] Kenneth Marshall, "Bruning: Another Way to Organize Physical Distribution Management," *Handling & Shipping* (November 1966), pp. 61–66.

Manufacturing industries are characterized by firms that purchase a wide variety of items from many suppliers for transforming them into items of relatively high value. There is substantial logistics activity, both on the supply side and the distribution side of these firms. Organization design includes both materials management and physical distribution.

Organizational Development

The philosophy about what is good logistics/SC management and the resulting organizational design has been evolving over the years. Bowersox and Daugherty have noted three distinct stages of development.[3] Stage I, which could be observed in the early 1970s, represented a clustering of activities that were important to realizing the cost trade-offs inherent to logistics management. Transportation activities were managed in concert with inventory and order-processing activities to achieve physical distribution cost and service goals. Purchasing, inbound transportation, and raw materials inventories were collected together under a single organizational banner for coordination. The recognition of the activities relevant to physical distribution and physical supply and the need for their careful coordination were there in the early 1970s, but organizational structures were rather weak. Many firms would rely on informal arrangements such as persuasion and staff coordinators to balance the interests among the activity areas. Since organizational design change seems to be more of an evolutionary process than a revolutionary one, early attempts at logistics organization were carried out without radical change to the "in-place" organizational structure.

The Stage II organization was directed at formal structures, where a top-level executive was placed in charge of the relevant logistics activities, usually those of physical supply or physical distribution, but not both. This gave direct control over the coordination of the logistics activities. This was an evolutionary step, as the benefits of good logistics management became better understood and appreciated among firms. Companies such as Kodak and Whirlpool were early leaders in this type of formalized structure. However, in 1985 larger firms (42%) remained in Stage I[4] or had moved on to Stage III (20%).

Stage III organization structure referred to the full integration of logistics activities, spanning both physical supply and physical distribution. Total integration of logistics activities, and the organizational structure of a scope to coordinate them, increased in popularity. Total integration was driven by the just-in-time, quick response, and time compression philosophies that required precise coordination among all activities throughout the entire firm. In addition, shared assets such as a truck fleet or warehouses that were used in both physical supply and physical distribution activities also required careful coordination to achieve their maximum utilization.

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[3] Donald J. Bowersox and Patricia J. Daugherty, "Emerging Patterns of Logistical Organization," *Journal of Business Logistics*, Vol. 8, No. 1 (1987), pp. 46–60.

[4] A. T. Kearney, *Emerging Top Management Focus for the 1980s* (Chicago: Kearney Management Consultants, 1985).

Example

Micro-Kits sold one of its products—a toolkit for field repair of PC hardware—through three market channels: (1) retail stores; (2) catalog customers; and (3) wholesale customers. It purchased components from vendors and shipped them to a plant for assembly. Finished goods were shipped to a distribution center from which sales orders were filled. A JIT system was proposed that would mainly improve operating performance in the physical supply channel and in production.

The entire logistics and production channel was modeled using computer simulation. The results showed that JIT would make a substantial improvement compared with current operations. That is, the profit margin would increase by 106 percent, inventory turnover would increase from 7.2 to 7.8:1, and the channel lead time would be reduced from 24.2 to 13.7 days.

However, this view was shortsighted. By planning the entire channel in an integrated fashion where physical distribution and physical supply are planned collectively, further improvement was possible. Profit margins could be increased by an additional 6 percent, inventory turnover could be increased from 7.8 to 16.3:1, and the channel lead time reduced from 13.7 to 8.9 days.

It is this type of benefit from integrated planning that is also driving organization structure to span both physical supply and physical distribution activities.[5]

Now a Stage IV is being referred to as supply chain, or integrated logistics, management. This involves the full integration of the logistics activities of Stage III, but includes the logistics activities within the product transformation processes (production). That is, companies in Stage IV of their organizational development will view logistics as encompassing all those activities that take place between their sources of raw materials, through production, and on to the final consumer. The significant difference between Stage III and Stage IV is that the activities of the product transformation process such as product scheduling, work-in-process inventory management, and coordination of just-in-time scheduling both inbound and outbound are now included in the scope of integrated logistics.

Safexpress Private Limited, one of the leading logistics companies in India, provides integrated logistics management, express, air, multimodal, door-to-door, time definite delivery, and consultancy services. Its network spans over 525 destinations, spread across 28 states and 7 union territories with modern information technology systems and over 2,400 containerized vehicles. Safexpress delivers over 2.5 million packages a month. Its warehousing space is spread over two million square feet. The company is also associated with Indian Airlines and other air taxi operators to carry out its door-to-door service. It also provides services to portals such as BuyAsOne.com, BigRupee.com, and KhulJaSimsim.com. In addition, it has alliances with Panalpina World Transport (India) Private Limited and Miebach Consulting Group for offering 3PL and supply chain management (SCM) services.[6]

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[5] Robert Sloan, "Integrated Tools for Managing the Total Pipeline," *Annual Conference Proceedings*, Volume II (St. Louis: Council of Logistics Management, 1989), pp. 93–108.

[6] Available at http://www.safexpress.com.

A Stage V can be envisioned where logistics activities will be managed *between* firms in the supply channel that are separate legal entities. To this point, managerial attention has primarily focused on those logistics activities that are within the immediate control and responsibility of the firm. Managing this superorganization will bring new challenges, but it will also bring opportunities for efficiencies not yet tapped by current organizational thinking and structures.

ORGANIZATIONAL CHOICES

When the need for some form of organizational structure has been established, there are basic choices from which a firm may select. These can be categorized as informal, semiformal, and formal types. No type is dominant. Organizational choice for any particular firm is frequently a result of evolutionary forces operating within the firm. That is, the logistics organizational form is often sensitive to the particular personalities within the firm, to the traditions regarding organization, and to the importance of logistics activities.

The Informal Organization

The major objective for logistics/SC organization is to achieve coordination among logistics activities for their planning and control. Given a supporting climate within a firm, this coordination may be achieved in a number of informal ways. These typically do not require any change in the existing organizational structure, but rely on coercion or persuasion to accomplish coordination among activities and cooperation among those who are responsible for them.

For firms that have designated separate areas of responsibility for such key activities as transportation, inventory control, and order processing, an incentive system can sometimes be created to coordinate them. Whereas the budget, which is a major control device for many firms, is often a disincentive to coordination, it can sometimes be turned into a mechanism for effective coordination. The budget may be a disincentive because a manager of transportation, for example, would find it unreasonable to incur higher than necessary transportation costs in order to achieve lower inventory costs. Inventory costs do not fall within the transportation manager's budget responsibility. The transportation manager's performance is measured by how transportation costs compare with the budget.

One possible incentive system to encourage cross-activity cooperation is to establish a number of cross charges or transfer costs among the various logistics activities. Consider how a transportation selection decision might be made when it indirectly affects inventory levels, but the transportation decision maker is unmotivated other than to seek the lowest possible transportation costs.

Example

Suppose that the inventory manager in a firm is to permit higher-than-desired levels of inventory in order to accommodate a less expensive but slower means of transportation, resulting from shipping in larger quantities. To the extent that the inventory costs are increased above the desired inventory levels, as determined strictly by inventory objectives, the incremental costs incurred above this level are charged to the transportation manager's account. The transportation manager can realistically appraise the impact of his or her transport selection decision on inventory costs and make a choice that balances costs across the firm by simply following his or her own budget objectives.

Another incentive is to establish some form of a cost saving and sharing arrangement. All managers of the separate logistics activities that show conflicting cost patterns could pool their cost savings. A predetermined schedule could be established to divide the savings for redistribution to salaries. There is incentive for cooperation because the greatest potential savings come about when cooperation leads to a balancing of activities having conflicting cost patterns. These so-called profit-sharing plans have had limited success among firms, but a few firms have used them effectively (e.g., Lincoln Electric).

The use of coordinating committees is another informal approach to logistics organization. These committees are made up of members from each of the important logistics areas. By providing a means through which communication can take place, then coordination may result. For companies in which there is a history of coordinating committees, the committee form can be quite satisfactory. Dupont is one example of a company famous for its effective management by committee. Although committees seem to be a simple, straightforward solution to the coordination problem, their shortcoming is that they generally have little power to implement their own recommendations.

A chief executive's review of logistics decisions and operations is a particularly effective way of encouraging coordination. Top management has the necessary position in the organizational structure to easily observe suboptimal decision making within the organization. Because subordinate managers in the logistics activity areas are responsible to top management, top management's encouragement and support of coordination and cooperation among these interfunctional activities goes a long way toward achieving the organizational goals without a formal organizational structure.

The Semiformal Organization

The semiformal organization form recognizes that logistics planning and operation usually cut across the various functions within a firm's organizational structure. The logistician, or supply chain coordinator, is then assigned to coordinate projects that involve the supply chain and that cover several functional areas. This type of structure is often called a *matrix* organization, and it has been especially popular in the aerospace industry. The concept has been adapted to logistics system management, as shown in Figure 15-2.

In a matrix organization, the logistics/SC manager has responsibility for the entire logistics system, but he or she does not have direct authority over the component activities. The traditional organizational structure for the firm remains intact, yet the logistics/SC manager shares the decision authority and accountability with the activity area manager. Expenses for the activities must be justified by each functional department as

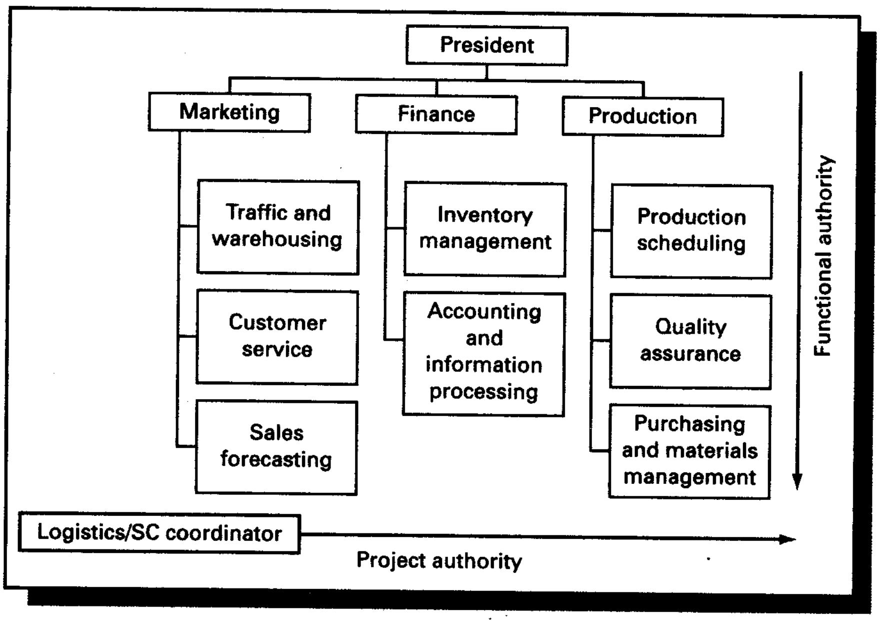

Figure 15-2 A Logistics/SC Matrix Organization

well as by the logistics program, which is the basis for cooperation and coordination. The logistics/SC coordinator may even assist in coordinating logistics activities among member firms of the supply channel beyond the boundaries of his firm.

Although the matrix organization can be a useful organizational form, we should recognize that the lines of authority and responsibility become blurred. Conflicts may arise that cannot be easily resolved. However, for some firms this choice is a good compromise between an informal form and a highly structured one.

Example

United Fixtures manufactures plumbing hardware, with sales in the $80 million range. This firm recently created a distribution department to solve logistics problems. The new manager reported to the vice president of sales and marketing. The department was given the objective of defining customer service standards and then coordinating those standards with delivery schedules and production plans.

The sales department had previously been routing production orders from the plant to please large customers, and production control personnel could not keep up. The new department was quickly able to identify the bottleneck and institute a system that better coordinated order entry, production schedules, field warehousing, and transportation to meet customer demands.

At the same time, sales personnel devised new methods of circumventing the schedules, once again accommodating favored customers. Purchasing personnel further confounded the situation by complaining at length about the widely different materials requirements because of new production schedules.

Despite the favorable impact on transport costs and better on-time delivery, a number of problems remained. Most functions in the firm that interfaced or participated in the materials movement system felt that the distribution department was interested only in bettering a system that helped finished goods distribution. Furthermore, the distribution manager was upset because he had not been able to gain control over the inventory of finished goods. The vice president of manufacturing was "responsible for stock control for the company" and was not about to release control over finished goods.

The company was persuaded to implement a form of matrix organization. Substantial success has been achieved, but some difficulties have been experienced with the shared authority obstacle. An executive vice president in charge of materials was appointed. In this job, he had no responsibility for a large staff nor did he have any departments reporting to him. Owing in part to his prestigious title and his tactful approach, he and two assistants were nevertheless able to achieve the kind of overall coordination that had eluded other functional organizations.[7]

The Formal Organization

The formal organization is one that establishes clear lines of authority and responsibility for logistics/SC. This typically involves (1) placing a manager in a superior position relative to logistics activities; and (2) placing the manager's authority on a level in the organization's structure that allows effective compromise with the other major functional areas of the firm (finance, operations, and marketing). This elevates and structures logistics personnel in a form that promotes activity coordination. Firms seek the formal organizational form when less formal arrangements prove ineffective or when greater attention is to be given to logistics activities.

Practitioners frequently remind us that there is no such thing as a typical organization for logistics. Organizational structure is customized to individual circumstances within a firm. However, we can develop a generalized formal organization that makes good sense in terms of logistics management principles and appears, in at least partial form, in enough firms to use it as a model. This organizational structure is shown in Figure 15-3. It serves as a valuable guideline.

This formal design accomplishes several important ends. First, logistics/SC is elevated to a position in the organization where it is managed with the same authority as the other major functions. This helps to ensure that logistics activities receive the same attention as marketing, operations, and finance. It also sets the stage for the logistics manager to have an equal voice in resolving economic conflicts. Having logistics on a par with the other functional areas creates a balance of power for the economic good of the firm as a whole.

Second, a limited number of subareas are created under the chief logistics/SC officer. The five categories shown in Figure 15-3 are established with a separate manager for each and are managed as a distinctive entity. Collectively, they represent the major

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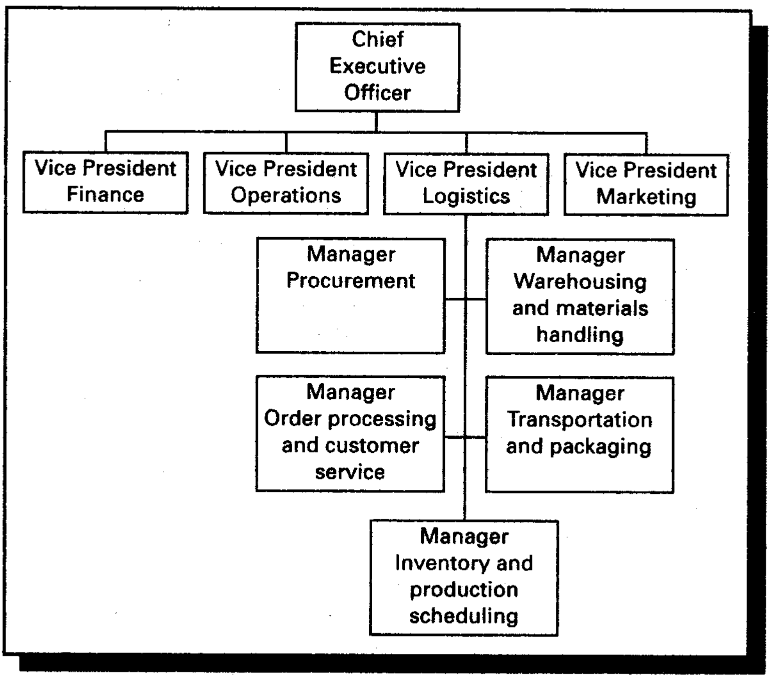
[7] Daniel W. DeHayes Jr. and Robert L. Taylor, "Making 'Logistics' Work in a Firm," *Business Horizons* (June 1972), pp. 38 and 45. Copyright © 1972 by the Foundation for the School of Business at Indiana University. Used with permission.

Figure 15-3 A Formalized, Centralized Organizational Structure for Logistic/SC



activities for which managers are typically responsible.[8] Why are there exactly five areas? Only as many areas are created as technical competencies require. It might seem desirable to combine, say, transportation and inventory activities into a single area because their costs are naturally in conflict and better coordination could be achieved. However, the technical skills required in each area are substantially different, so finding management for the combined areas having both types of skills is difficult. It is often more workable to keep such activities under a separate manager and rely on the logistics manager to establish coordination through the informal or semiformal organizational types previously discussed. Similar arguments can be offered for the other activity areas. Therefore, the formal organization structure is a balance between minimizing the number of activity groups to encourage coordination while separating them to gain effectiveness in the management of their technical aspects.

The organizational form in Figure 15-3 is the most formalized and centralized that is generally found in industry today. It is a structure integrating both materials management and physical distribution under a single banner. Relatively few firms have, in fact, achieved this degree of integration (20% in 1985),[9] but cost and customer service trends are likely to increase its popularity. However, the basic model is useful, whether a firm organizes its logistics operations around supply-side activities, as in the case of many service firms, or around physical distribution activities, as in the case of many manufacturing firms.

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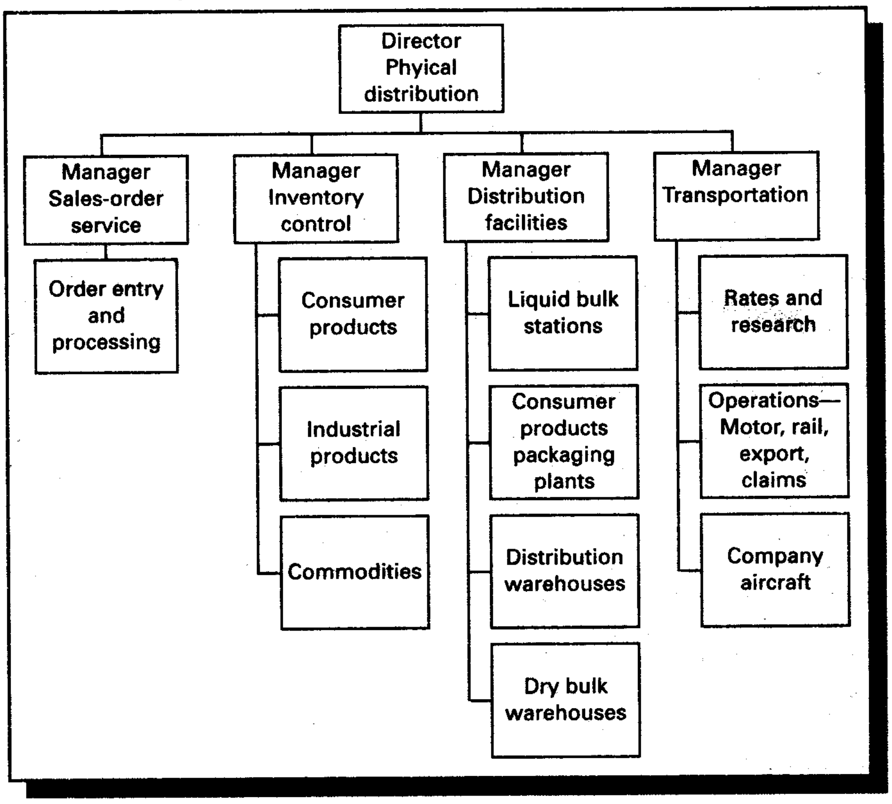
[8] Bernard J. LaLonde and Larry W. Emmelhainz, "Where Do You Fit In?" *Distribution*, Vol. 8, No. 11 (November 1985), p. 34.
[9] A. T. Kearney, Emerging Top Management Focus for the 1980s.

Example

Several years ago, a producer of corn and soybean products reorganized its distribution activities. Because of high shipping volumes, a great deal of attention was paid to traffic activities, with a vice president of traffic as a member of the board of directors. Performance of the traffic division was measured by the dollar size of the freight bill. Partly because of this, the distribution system grew to contain over 350 inventory-stocking points.

Because of an outside consultant's study and top management's support, the finished product service functions were grouped under one director. This integrated function is shown in Figure 15-4 and was created from the organizational fragments found throughout the company. A member of the marketing group was selected as the new head of physical distribution. Not only did the new organization result in greater control over the finished product, but also the number of late shipments was reduced by 88 percent, and greater stock availability was provided in the marketplace. This was all achieved at a lower total cost.

Figure 15-4 Distribution Division Organizational Design for a Producer of Corn and Soybean Products



The results of distribution organization were so impressive that supply-side activities have been grouped under one executive and called materials management. Note how this organizational design was evolving toward that shown in Figure 15-3.

ORGANIZATIONAL ORIENTATION

According to a Michigan State University study of Fortune 500 firms, the type of organizational structure to be selected was found to depend on the particular strategy that the firm was pursuing.[10] Organizational design seems to follow three corporate strategies: process, market, and information.

Process Strategy

A process strategy is one where the objective is to achieve the maximum efficiency in moving goods from a raw materials state through work in process and on to a finished-goods state. Organization design is likely to focus on the activities that give rise to cost. That is, activities such as purchasing, production scheduling, inventory, transportation, and order processing will be collected together and managed collectively. The actual form of the organization will most probably be of the types previously discussed.

Market Strategy

Firms pursuing a market strategy have a strong customer service orientation. Both sales and logistics coordination are sought. The organizational structure is not likely to integrate the logistics activities that are inherent under the process strategy. Rather, those activities directly relating to customer service for both sales and logistics are collected together and often report to the same executive. The organizational structure is likely to span across business units to a high level of customer service. Of course, logistics costs may not be held at their lowest level.

Information Strategy

Firms that pursue an information strategy are likely to be those that have a significant downstream network of dealers and distribution organizations with substantial inventories. Coordination of logistics activities throughout this dispersed network is a primary objective, and information is the key ingredient for good management. In order to secure this information, the organizational structure is apt to span functions, divisions, and business units. When logistics activities span the legal boundaries of channel members, such as when goods are placed on consignment in retail outlets or returned goods are handled by the buying firms, information must be obtained across these organizational boundaries. Thus, the organizational structure must span the traditional legal boundaries of the firm itself.

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[10] Bowersox and Daugherty, "Emerging Patterns of Logistical Organization."

We should recognize that no firm is likely to display a single organization design. Because mixed strategies often exist within the same firm, a variety of designs will appear for essentially similar firms. In addition, similar firms may be in different stages of organizational development. This can make it difficult to explain the rationale for any particular structure just from its design.

ORGANIZATIONAL POSITIONING

Organizational choice and orientation are the first considerations in organizational structure. Next comes the positioning of logistics activities for their most effective management. Positioning concerns *where* to place these activities in the organizational structure. This is determined by such issues as (1) decentralization versus centralization; (2) staff versus line; and (3) large company size versus small.

Decentralization Versus Centralization

One of the continuing controversies in organization is whether activities should be grouped close to top management or dispersed throughout the divisions of the larger firms. For example, a major electric company had a number of product divisions, such as industrial electrical equipment, nuclear power, small appliances, major appliances, and lamps. A centralized organization groups logistics activities at the corporate level for serving all product groups, as shown in Figure 15-5. On the other hand, the decentralized logistics organization puts the responsibility for logistics at the product group or division level, as shown in Figure 15-6. A separate decentralized logistics organization is established to serve each division.

There are some obvious advantages to each type, and a number of firms create organizational forms that blend both types to seek their combined advantages. The principal reason for the centralized form is to maintain close control over logistics activities and to benefit from the efficiencies associated with the scale of activities that can occur by concentrating all logistics activities for the entire corporation under a single director. Consider the traffic activity as an example. Many firms own private truck fleets. Utilization of the equipment is the key to efficiency. By having centralized control of all traffic activities, a firm might find that the forward haul of one division's products might be the back haul for another. These movements can then be balanced, whereas under a decentralized organization they might be overlooked. Similar efficiencies can be gained through shared warehousing, shared purchasing, and shared data processing.

Decentralization of organization often allows quicker and more customized logistics response to customer needs than the more removed, centralized organization. Decentralization makes a great deal of sense when product lines are distinctly different in their marketing, logistics, and manufacturing characteristics, and when few economies of scale can be found.

Rarely can we expect to find either a purely centralized or a purely decentralized design. For example, although there is managerial interest in divisional and even regional autonomy among the operating units of a firm, technical advances such as

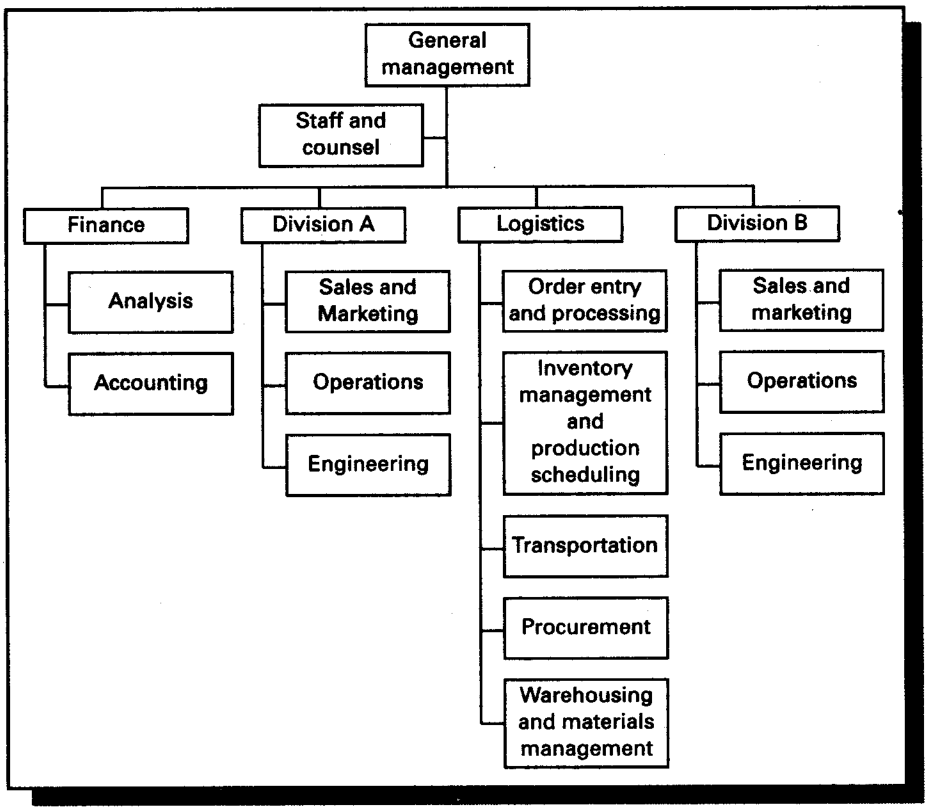

Figure 15-5 A Generalized Example of a Centralized Logistics/SC Organizational Structure

computerized data processing have made it more efficient to have centralized order processing and inventory control. Such conflicting trends help to explain the diversity of organizational forms in practice.

Staff Versus Line

A number of firms do not create organizations that have direct or line responsibility over goods movement and storage. They find it more satisfactory in their circumstances to establish an advisory, or staff, organization for logistics. The logistician in this case is placed in a consulting role to the other line functions such as marketing and operations. An advisory organization is a good alternative when (1) a line organization would cause unnecessary conflicts among the existing personnel; (2) logistics activities are less critical than selling, producing, and other activities; (3) planning is relatively more important than administration; and (4) logistics is treated as a shared service among the product divisions.

The staff type of organization may be attached to any of the functional areas at a centralized or decentralized level. Frequently, however, the logistics staff is located

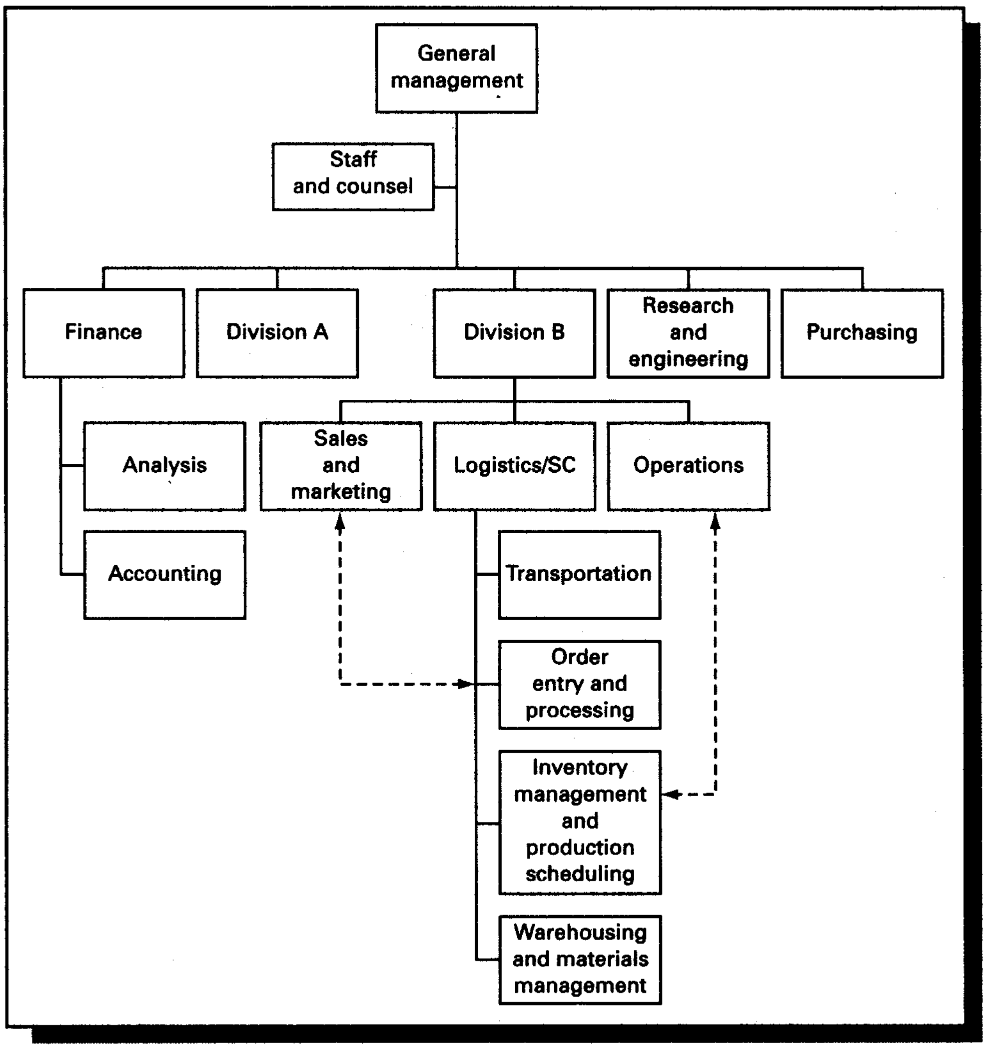

Figure 15-6 A Generalized Example of a Decentralized Logistics/SC Organizational Structure

near top management in geographical location and on the organization chart. Because the logistics staff is in an advisory role, authority that is more indirect can be given to logistics through this type of organizational positioning. In fact, some corporate level logistics staffs wield more authority than many division-level line organizations.

Large Versus Small

Most of the attention given here has been to the large, multidivisional firm. What about the small firm? We should recognize that the small firm has just as many logistics key idea in supply chain management and is only now being actively pursued by researchers and practitioners.

The Superorganization

The superorganization is a group of firms related through their business processes and mutual objectives (satisfying customers and maximizing profits), but who are legally separate. They share a common interest in the individual decisions made by each, since the decisions of the other firms can affect their performance, and vice versa. For example, a carrier's pricing decision will influence the decision of the carrier's customer on how much service to purchase. The customer's purchase decision, in turn, influences the carrier's pricing decision. Normally, each firm makes its decision while pursuing individual goals. If profit maximization is the goal, making the purchase and price decisions individually not only leads to suboptimal profits for the firms taken collectively, but they also can result in suboptimal profits for the firms individually. Management of the superorganization is a relatively easy task if the cooperative efforts yield proportionately greater returns to each member and they are distributed fairly. The situation is self-motivating for the members, and the only need is to become aware of the possibility and benefits of cooperation. However, if the benefits of cooperation "pool" (disproportionately favor) with one or a few of the channel members, equitably distributing the benefits and dispersing information among the members about the effects of cooperation is needed.

Example[13]

Conflicts and opportunities within the superorganization can be illustrated through a simple, hypothetical example. Suppose that a supply channel consists of a buyer and a seller. The seller prices an item to the buyer and the buyer decides on the quantity to purchase. Demand on the buyer is relatively predictable and stable; the buyer determines the purchase quantity from the economic order quantity formula to minimize procurement and inventory-holding costs. The potential conflict in the channel arises when the order quantity for the buyer is not the preferred order quantity for the seller.

The buyer is an original equipment manufacturer producing $D = 10{,}000$ units of a certain model at a constant rate. This firm purchases a component for this model from an upstream supplier. Each time the buyer places an order, an ordering cost associated with administrative details, transportation, and so on is incurred. This ordering cost is $S_b = \$100$. The buyer also incurs an inventory-carrying cost of $I = 20\%$ per year for the component valued at $C = \$50$ per unit. Obviously, the buyer will attempt to determine an order quantity (Q_b) that balances ordering costs against

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[13] Paraphrased from Ronald H. Ballou, Stephen M. Gilbert, and Ashok Mukherjee, "New Managerial Challenges form Supply Chain Opportunities," *Industrial Marketing Management*, Vol. 29, No. 1 (2000), pp. 7–18, with permission from Elsevier Science.

inventory-holding costs. From the EOQ formula (recall Equation 9-7), the optimal order quantity for the buyer is

$$Q_b^* = \sqrt{\frac{2DS_b}{IC}} = \sqrt{\frac{2(10{,}000)(100)}{(0.2)(50)}} = 447 \text{ units}$$

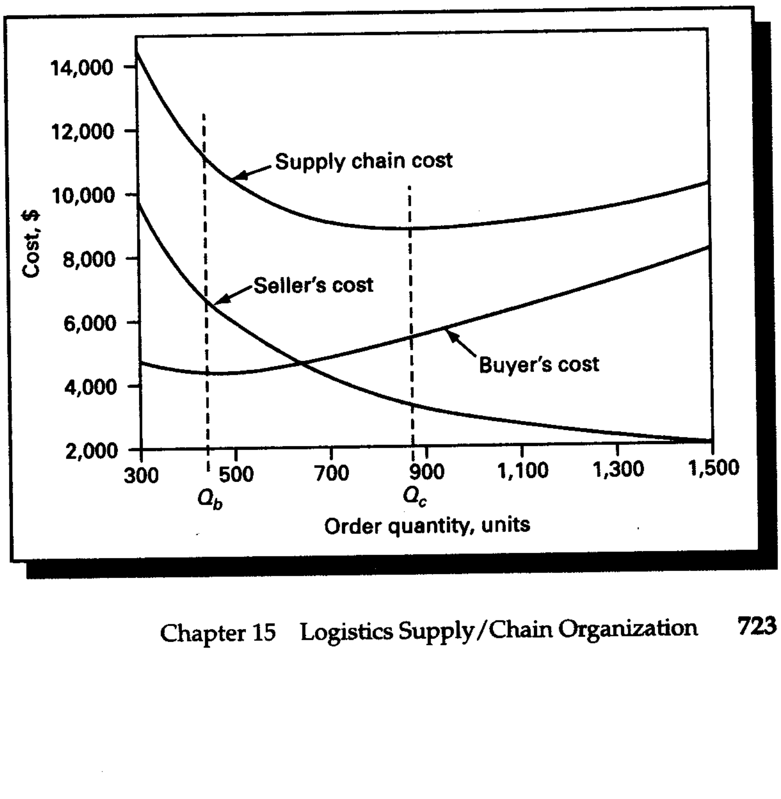
The supplier produces to order whenever one is received from the buyer. Each time the seller sets up to produce a batch of components, a production setup cost of S_s = \$300 is incurred, and the total annual setup cost (C_s) depends on the *buyer's* order quantity: $C_s = \$300D/Q_b$. The more frequently the buyer places orders, the more setup costs are imposed on the seller.

The optimal order quantity from the buyer (Q_b) is not the same as the optimal order quantity for the entire supply chain (Q_c). These two order quantities are labeled Q_b and Q_c, respectively, in Figure 15-7. If the supply chain were owned and operated by a single firm, the total cost of ordering and setting up for a batch of components would be $S_c = S_b + S_c$. The total inventory-carrying cost would be the carrying cost incurred by the buyer, *IC*. The optimal order quantity for the channel would be

$$Q_c^* = \sqrt{\frac{2D(S_b + S_s)}{IC}} = \sqrt{\frac{2(10{,}000)(100 + 300)}{(0.2)(50)}} = 894 \text{ units}$$

Unfortunately, when the buyer and the seller are legally separate entities, the buyer lacks motivation to deviate from his optimal order quantity of 447 units, even though the total costs to the supply chain would be lower if he did. In fact, the total setup and inventory carrying costs incurred by the supply chain are 25 percent higher, because the self-interested decision of the buyer causes him to order in quantities that are

Figure 15-7
Cost Curves for the Buyer, Seller, and Supply Chain



	Buyer Optimal, Q_b = 447 Units	Supply Chain's Optimal, Q_c = 894 Units	Cost Change From Buyer's Optimal, Q
Seller[a]	$ 6,711	$3,356	–50%
Buyer[b]	4,472	5,589	+25%
Supply chain[c]	11,183	8,945	–20%

[a] $TC_s = S_s D/Q_s$

[b] $TC_b = S_b D/Q_b + ICQ_b/2$

[c] $TC_c = (S_s + S_b)D/Q_c + ICQ_c/2$

Table 15-1 Annual Costs for Buyer, Seller, and Supply Chain under Various Order Quantities in Units

about half as large as what is optimal for the supply chain. The economic situation is summarized in Table 15-1 and is shown graphically in Figure 15-7.

It is clear that supply chain costs can be reduced by switching to order quantities based on the costs for the entire supply chain, rather than letting the buyer dictate the order size. If it were true that switching to the optimal order quantity for the supply chain resulted in *both* the seller and the buyer realizing lower costs, the channel would be economically stable, that is, no member wishes to alter the order quantity since his costs would be higher. As seen in Table 15-1, if a switch were made to the supply chain optimal quantity, the seller could benefit at the expense of the buyer, whose costs would increase by 25 percent. Since the buyer controls the quantity, he will not order the supply chain optimal quantity unless the benefits are redistributed to reward him for doing so. The benefits are accumulating with a channel member who is not responsible for creating them. Ways need to be found for resolving this conflict.

Managing the Conflict

The object of managing the superorganization is to establish the conditions so that each member of the coalition may benefit from his or her cooperation for the greater good. Managing the superorganization is not the same as managing within the confines of the firm. The reliance is more on bargaining and tacit arrangements than on formalized structural relationships. This type of management is generally little understood and is a subject for further research. However, the direction for successful superorganization management seems clear. First, metrics need to be established for identifying boundary-spanning opportunities and measuring performance due to cooperation. Second, there need to be ways of sharing relevant information among the superorganization members. Third, there needs to be the application of a strategy for conflict resolution. Fourth, there needs to be some method for distributing the gains achieved from cooperation and maintain the coalition.

Need for Metrics

Uncovering cost-saving/service-improvement opportunities in the supply chain from managing across company boundaries and quantifying them requires an accounting system that few possess. Multienterprise accounting would need to report such costs as inventory holding, transportation, order or production setup, product storage and handling—all the costs, demand, and service information associated with product flows between the firms. Channel members must be able to evaluate the effect of their decision making on their performance as well as that of other members. They need to know where the benefits "pool" in the channel and to quantify the changes in logistics performance. Measures that specifically address boundary-spanning issues such as total channel cost/profit, total order cycle time, and channel productivity should be a part of channelwide reporting. Many of the metrics that firms use internally for their own managerial purposes need to be extended to their supply chain partners. Whatever form the metrics take, they should *encourage* the identification and measurement of superorganization opportunities.

Information Sharing

An adequate information base in the superorganization is needed for at least two reasons. First, in order for each firm to adjust its controllable variables so that optimum channel profits are achieved, knowledge is required of the economic factor inputs to the decision problems facing the other members, as well as accounting information on the level of profits accruing to each member. Second, an adequate information system also reduces the uncertainties among the autonomous members and contributes to their continued voluntary cooperation. An intermember information system could be established, but assuring adequate and accurate information among the membership is difficult because of the weak lines of accountability. However, sharing information related to the cooperative effort is essential since it helps to build trust among the members, a key ingredient for encouraging and maintaining cooperation.

Distribution of Benefits

Equitable redistribution of the benefits achieved through cooperation by the coalition is important. Recall Table 15-1, especially column 3. Under the revised order quantity, channel costs are at their lowest level, but the change in costs (see column 4) is not distributed equitably among the members. That is, both seller and the channel stand to gain from the buyer's change in order quantity. However, the buyer stands to lose as costs increase. The buyer lacks the incentive to cooperate since he can profit more by acting alone, as can be noted from his cost figures for Q_b in Table 15-1. The buyer might drop from the coalition. If a method for the redistribution of costs, possibly in proportion to the cost levels that are likely to exist under the situation where both members act alone, were established, each member could be satisfied. The buyer recovers the cost level he would have gained from acting alone, in addition to sharing in the additional cost benefits achieved through cooperation. Both members are likely to remain in the coalition, since both derive benefits from it. However, establishing a method for passing the benefits between channel members that will keep them acting in concert may be elusive.

Strategies for Conflict Resolution[14]

When cooperation produces an equitable distribution of benefits among channel members, no formal action is needed to redistribute the benefits. All members are better off and may be satisfied with the outcome. However, if the members believe that they gain, but inequitably or the benefits "pool" with some members at the expense of others, then there is a choice of using a formal or informal transfer mechanism.

A *formal* transfer mechanism is one where a product-flow variable under the control of one channel member can be altered in such a way to influence the action of another member to cause the systemwide optimum to be achieved. An example in the previous illustration would be to adjust price in the channel that is under the seller's control. In Table 15-1, the buyer's costs are shown to increase by $1,117 per year if he agrees to an order quantity of 894 units, whereas the seller's costs are reduced by $3,355 for this quantity. If the seller transfers some of his benefits in the form of a price discount that reduces the buyer's annual costs by a least $1,117, an economically rational buyer will take the incentive and order the supply chain optimal quantity. Although price is one variable that can be manipulated to achieve the redistribution of benefits, other formal transfer mechanisms might include order minimums, reapportionment of orders among channel members to reward cooperation, and incentives on future orders, depending on the configuration of the channel and where in the channel the benefits tend to collect.

Ensuring cooperation in a supply chain when a formal transfer mechanism is not present or is not to be used requires other mechanisms that are less direct and obvious, that is, *informal*. Informal cooperative mechanisms arise outside the scope of traditional economic understanding of exchange since, unlike the economic theory of pure and perfect competition, there is no development of a theory of pure and perfect cooperation.

At least two major and distinct informal mechanisms, *power* and *trust*, can be used to generate cooperation in a supply chain. These mechanisms are usually regarded as alternatives to each other. Power is a central concept because its mere existence is thought to condition others. Power is also seen as a central tenet in achieving cooperation. In contrast, it is theorized that central to relationship marketing is the presence of trust, not power, and its ability to condition others.

Consider the role of power as a mechanism to achieve cooperation. The exercise of power by a channel member might be used especially against the one worse off because of cooperation. A member might be so dominant that other members may be coerced into acting to achieve the systemwide benefits. In the example, if the seller has the status of being the only supplier, he might coerce the buyer to accept purchasing in the larger quantity. The buyer may have to accept the additional costs as a pseudo price increase, yet the seller has not changed his pricing policy with the attendant legal problems that might be involved.

Additional forms of power include reward power, expert power, and referent power. An example of *reward power* is to establish the buyer as a preferred customer, which might include for him faster and easier transactions or guaranteed service

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[14] Ibid.

regarding quantity availability and delivery time. The benefit to the buyer is the reduction of uncertainty. Similarly, a member might use *expert power*. In this case, the seller might provide training, information, or problem-solving assistance as an incentive for cooperation. Another might be the use of *referent power*. Here, the seller's brand name or image may be so strong that the buyer may be permitted to use it in his advertising and to his benefit (e.g., Intel Inside). This is an indirect benefit to the buyer, who then may agree to supply chain cooperation. If the value of these incentives exceeds the $1,117 cost increase experienced by the buyer, then a rational buyer is likely to accept ordering in the larger order quantities.

Another informal mechanism, *trust*, is defined as a general expectancy held by a channel member that the word of the other can be relied on. That is, one party has confidence in an exchange partner's reliability and integrity. Once trust is established, parties learn that coordinated, joint efforts lead to outcomes that exceed what the firm can achieve acting solely in its own interest, which is exactly the phenomenon illustrated in the example. In buyer-supplier bargaining situations, trust is found to be central to the process of achieving cooperative problem solving and constructive dialogue.

Trust may lead directly to cooperation, or indirectly through development of commitment, which then leads to cooperation. A partner committed to the relationship will cooperate with another because of a desire to make the relationship work. In interfirm relationships, commitment and trust are seen to have strong positive relationships with cooperation. The concepts of trust and commitment are used as mechanisms to enhance relationship marketing, which refers to unique value-added partnerships for which the buyer may be willing to pay a price.

Given that trust and commitment lead to the desired outcome of supply chain cooperation, what are the precursors of trust and commitment in a supply chain? A major precursor of trust is *communication*, which can be defined broadly as the formal as well as informal sharing of meaningful and timely information between channel members. Information sharing is one of five building blocks that characterize solid supply chain relationships, according to LaLonde.[15] Timely communication fosters trust by assisting in resolving disputes and aligning perceptions and expectations about the benefits of cooperation. This accumulation of trust, in turn, leads to better communication. Thus, relevant, timely, and reliable information will result in greater trust. New ways of information sharing, as well as sharing of information between parties usually held in private, can be vital in attaining supply chain cooperation.

Another precursor of trust is *shared values*. Shared values are the beliefs in common that partners have about what behaviors, goals, and policies are important or unimportant, appropriate or inappropriate, and right or wrong. Behavior results from (1) sharing, identifying with, or internalizing the values of an organization or (2) cognitive evaluation of the instrumental worth of continued relationship with an organization. Thus, shared values lead to trust and commitment, and, in turn, cooperation. In a supply channel, channel members are likely to share common economic goals.

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[15] Bernard J. LaLonde, "Building a Supply Chain Relationship," *Supply Chain Management Review*, Vol. 2, No. 2 (Fall 1998), pp. 7–8.

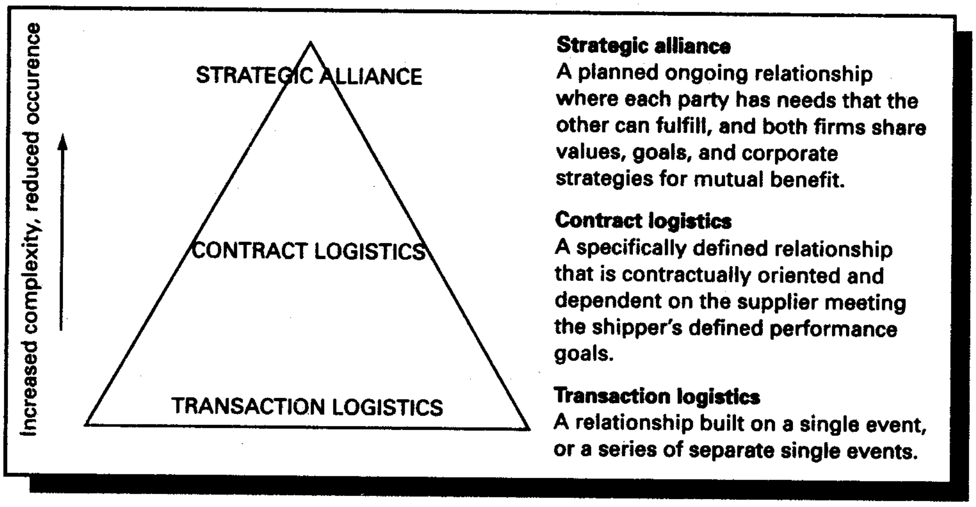
None of these methods can guarantee conflict resolution or force a particular channel member to perform in a manner that will benefit the channel as a whole. However, they should provide some guidelines for realizing the opportunities that lay dormant in managing the logistics channel among firms.

ALLIANCES AND PARTNERSHIPS

As an alternative to total ownership of the logistics capability and the need for an extensive logistics organizational structure or to loosely held together cooperative arrangements, some firms choose to *share* their logistics capability with other firms or to *contract* for the logistics activities to be performed by firms specializing in providing such services, called third-party providers (3PLs). Many firms are recognizing that there are strategic and operating advantages to be gained from logistics partnering. Some of the general benefits are

- reduced cost and lower capital requirements
- access to technology and management skills
- improved customer service
- competitive advantage such as through increased market penetration
- increased access to information for planning
- reduced risk and uncertainty

Of these, a potential reduction in transportation/distribution costs and freed up capital in noncore areas rank at the top of the benefits, with reduced personnel also being a noted advantage. The primary risk to the firm is the loss of control over critical logistics activities that may result in the potential advantages never being realized.



Strategic alliance
A planned ongoing relationship where each party has needs that the other can fulfill, and both firms share values, goals, and corporate strategies for mutual benefit.

Contract logistics
A specifically defined relationship that is contractually oriented and dependent on the supplier meeting the shipper's defined performance goals.

Transaction logistics
A relationship built on a single event, or a series of separate single events.

Figure 15-8 The Outsourcing Relationship Continuum

Source: "Strike Up Logistics Alliances," *Transportation & Distribution* (November 1988), pp. 38–42.

To some extent, firms have been outsourcing a portion of their logistics activities for many years. Every time a firm calls up UPS or a common carrier, or uses a public warehouse to store its goods, it is partnering with an outside firm to handle part of the supply chain activities. How extensive the relationship is between the firm and its outside partners is a matter of degree. The relationship may be based on single events to long-term contractual arrangements to shared systems of a strategic alliance. This outsourcing relationship continuum is illustrated in Figure 15-8.

Examples

Outsourcing logistics activities and partnering with others concerning logistical matters are quite common. Consider some of the opportunities for logistics cost reduction in several settings:

- MetroHealth, 1,000-bed community hospital, maintains a fleet of vans and drivers for transporting patients to and from its hospital complex to meet appointment times for examination and treatment. Vehicle and driver utilization is low, rarely exceeding 50 percent of the time available throughout the workday. Considering the cost pressures on the healthcare system, partnering with other area hospitals for this transport capability, while maintaining a desirable transport service level within the region, makes good economic sense, since hospital service territories typically overlap. Duplicate transportation systems could be avoided.
- A pharmaceutical manufacturer was constructing a new warehouse to meet its space needs for a considerable time into the future. The warehouse was sized to its future peak needs, and the fear of losing control over the inventory prohibited the company from seeking alternative space during the intervening years. Seeking partners to share the space for the time until the company needed to recapture the space due to inventory growth would save the expense of excess capacity. On the other hand, partners could acquire the space at rental rates, which were less than public warehousing or alternative contractual arrangements
- Abbott Laboratories and 3M consolidated their order entry and distribution functions for improved purchasing, materials handling, and inventory control. The two companies formed an alliance to allow hospitals to receive supplies from both firms through a single delivery. The alliance works well because the companies do not substantially compete with each other. The relationship has provided mutual marketing and distribution cost savings. IBM Information Network has joined the alliance to capitalize on increasing demand for on-line distribution service. Improved supply chain management and improved services for smaller suppliers are benefits of the alliance.[16]
- A survey conducted by the Centre for Supply Chain Management, Management Development Institute (MDI, India) found over half of the respondents outsourcing several logistics activities.[17] Outbound transportation is being

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[16] E. J. Muller, "The Coming of the Corporate Alliance," *Distribution*, Vol. 87, No. 8 (August 1988), pp. 82–84.

[17] *Industry* 2.0 (December 31, 2004), p. 66.

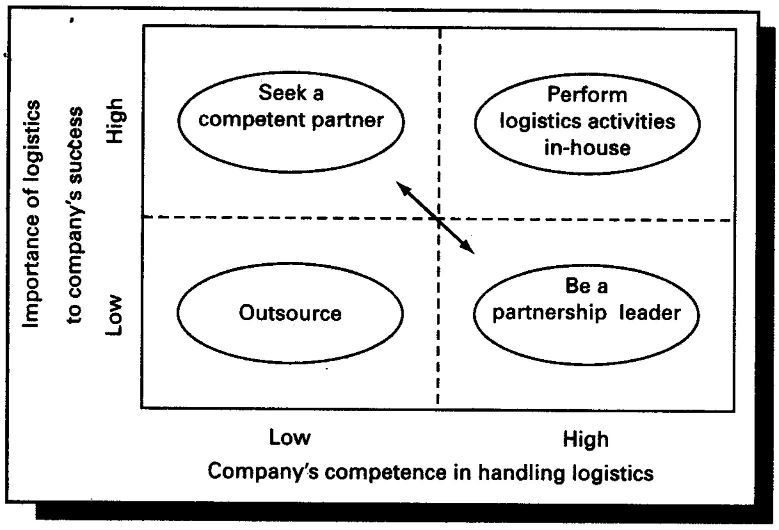

Figure 15-9
Selection Diagram of Where to Perform Logistics Activities

outsourced by 55.7 percent of the respondents followed by custom clearing and forwarding by 51.5 percent, outbound warehousing by 33.9 percent, inbound warehousing by 29.5 percent, import and export management by 34.5 percent, inventory management by 23.5 percent, and labeling and packing by 29 percent. Meanwhile, respondents not outsourcing logistics activities cited poor infrastructure and the inability of the providers to respond to changing needs as the main reason for not using 3PL providers.

Deciding whether to perform the logistics function in-house or to seek other arrangements is a balance of two factors: how critical logistics is to the firm's success and how competent the firm is in managing the logistics function. As shown in Figure 15-9, the strategy to follow depends on the position in which the company finds itself.

A company that has high customer service requirements, significant logistics costs as a proportion of total costs, and an efficient logistics operation administered by competent personnel will likely find little benefit to partnering or outsourcing logistics activities. Logistics activities are best performed in-house. Wal-Mart is a company that, because of its superior supply channel, has these characteristics. On the other hand, for those companies where logistics is not central to strategy and a high level of logistics competency is not supported within the firm, outsourcing the logistics activities to third-party providers may well lead to significant cost reductions and customer service improvements. Dell Computer considers its core competencies to be marketing and manufacturing high-technology PC hardware rather than logistics. This direct-marketing firm contracts with several third-party logistics providers to coordinate distribution in geographical areas.

Where logistics is critical to strategy but logistics management competency is low, finding a firm with which to partner may provide significant benefits. A strong partner may provide facilities located in new and existing markets, a transportation capability, and administrative expertise not available within the company. Conversely, where logistics is not especially critical to strategy but managed by capable personnel, managers may want to be aggressive by taking the lead in seeking partners to share the logistics system, thus reducing the company's costs through increased volume and the economies of scale that result. Target partners would be those companies that fall into the northwest quadrant of Figure 15-9.

Alliances

It is quite natural for a firm that is heavily invested in transportation equipment, warehouses, inventories, order processing systems, logistics technology, and administrative personnel to question whether this investment might be shared with other firms to reduce its own costs. Conversely, being conscious of the high costs of logistics, a firm may seek to partner with another firm that has excess logistics capacity, strategic facility locations to markets, desirable technology, and outstanding administrative capabilities that the firm seeks to share. Of course, the firm may have certain skills and capabilities that are desirable to other firms. Forming a logistics alliance, or partnership, may benefit both parties. The firm that does not desire to build a high degree of management competency in logistics may also seek an alliance with a stronger logistics partner to strengthen its own competitive position.

A logistics alliance is built on *trust*, a *sharing of information* that aids logistics performance, *specific goals* to achieve a higher level of logistics performance than can be achieved alone, operating *ground rules* for each partner, and *exit provisions* for alliance termination. The benefits to be derived from a logistics alliance have already been noted. If these benefits are so obvious, why is it that there are so few alliances that actually have been created? The answer may lie in the concerns that a potential partner has about the alliance when supply channels are to be merged. Chief among these concerns may include

- Loss of control over the logistics channel
- Fear of being "written out of the logistics picture"
- Increased concern about logistics failures and no direct way to handle them for their customers
- Adequate checks and balances may not be able to be identified to the satisfaction of the partner
- Difficulty of identifying the economies to be achieved as compared with the partner's current logistics costs
- A reporting system that does not match that of the partner's or one that is inadequate to reduce uncertainty
- Difficulty of identifying the benefits to be shared, especially when the partner has some ownership in the logistics system
- There may simply not be enough trust to try such an arrangement
- Partners may not be viewed as equals where one partner's requirements may take precedence over another's
- Difficulty in seeing how trust, good faith, and cooperation can be achieved in such an arrangement
- Too few examples to show how such alliances work well in other companies

Logistics alliances are fragile. They can be difficult to form and they may fracture easily; however, their potential benefits encourage management to continue to explore ways of making them work.

Example

A domestic manufacturer of electrical and power transmission equipment with annual sales of about $1.5 billion was quite proud of the logistics system it had created, especially the information system used to operate the system. Product was made to stock at nine plants and distributed nationally through eight warehouses and distributors. Pressures to reduce logistics costs led the company to consider a partner that would share the company's distribution system. Economies resulting from the additional volume flowing through the distribution channel would improve customer service and lower costs.

The company created an alliance with a European partner, who also manufactured industrial products and had annual U.S. sales of about $250 million. The product line was manufactured at two domestic plants with supplemental imports. Products were produced to stock, and national sales were served from three warehouses. The service levels to customers were similar for both partners.

The partnership primarily involved sharing the domestic firm's warehouse space in the California area. The domestic manufacturer was able to recover some of the fixed warehousing cost and better utilize the transportation equipment in the California marketplace. The European partner gained easy access to the California market, which it had not penetrated particularly well, and warehousing and delivery expenses were modest when compared with other alternatives.

HCL Infosystems Limited has entered into a strategic alliance with Apple to provide sales and service support for iPods in India. The company will set up distribution, logistics, and service network in the country. HCL intends to cover Delhi, Mumbai, Bangalore, Hyderabad, Kolkata, and Pune in the first phase. The company will also distribute Apple desktop computers to education, media, and entertainment segments. HCL has launched an entertainment portal to offer downloads for iPods, personal computers, and mobiles.[18]

Contract Logistics

For years, companies have been using the services of other companies to support their own logistics activities. Common carriers provide trucking and rail services, public warehouses provide storage services, and specialty firms provide freight bill auditing and accounting services. In recent years, mainly since the deregulation of transportation, logistics companies have emerged that provide a full-service logistics capability. That is, they can handle the entire logistics operation for a client company for a contract price. They have variously been referred to as third-party providers, integrated logistics companies, and contract logistics specialists. Although there has

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[18] Available at http://www.hclinfosystems.com.