technical note ten

FACILITY LOCATION

technical note

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Where should a plant or service facility be located? This is a top question on the strategic agendas of contemporary manufacturing and service firms, particularly in this age of global markets and global production. Dramatic changes in international trade agreements have made the world truly a "global factory," allowing companies greater flexibility in their location choices. In practice, however, the question of location is very much linked to two competitive imperatives:

1. The need to produce close to the customer due to time-based competition, trade agreements, and shipping costs.
2. The need to locate near the appropriate labor pool to take advantage of low wage costs and/or high technical skills.

This technical note discusses these and other issues in facility location decisions. Examples cover different industries with a global perspective. We present typical techniques involved in facility location analysis and two cases on global location decisions.

ISSUES IN FACILITY LOCATION

The problem of facility location is faced by both new and existing businesses, and its solution is critical to a company's eventual success. An important element in designing a company's supply chain is the location of its facilities. For instance, 3M has moved a significant part of its corporate activity, including R&D, to the more temperate climate of Austin, Texas. Toys Я Us has opened a new location in Japan as a part of its global strategy. Disney chose Paris, France, for its European theme park, and BMW assembles the Z3 sports car in South Carolina. Manufacturing and service companies' location decisions are guided by a variety of criteria defined by competitive imperatives. Criteria that influence manufacturing plant and warehouse location planning are discussed next.

Proximity to Customers For example, Japan's NatSteel Electronics has built its two largest plants in Mexico and Hungary to be closer to major markets in the United States and Europe—whose buyers want their goods delivered yesterday. Such proximity also helps ensure that customer needs are incorporated into products being developed and built.

Business Climate A favorable business climate can include the presence of similar-sized businesses, the presence of companies in the same industry, and, in the case of international locations, the presence of other foreign companies. Probusiness government legislation and local government intervention to facilitate businesses locating in an area via subsidies, tax abatements, and other support are also factors.

Total Costs The objective is to select a site with the lowest total cost. This includes regional costs, inbound distribution costs, and outbound distribution costs. Land, construction, labor, taxes, and energy costs make up the regional costs. In addition, there are hidden costs that are difficult to measure. These involve (1) excessive moving of preproduction material between locations before final delivery to the customers and (2) loss of customer responsiveness arising from locating away from the main customer base.

Infrastructure Adequate road, rail, air, and sea transportation are vital. Energy and telecommunications requirements also must be met. In addition, the local government's willingness to invest in upgrading infrastructure to the levels required may be an incentive to select a specific location.

Quality of Labor The educational and skill levels of the labor pool must match the company's needs. Even more important are the willingness and ability to learn.

Suppliers A high-quality and competitive supplier base makes a given location suitable. The proximity of important suppliers' plants also supports lean production methods.

Other Facilities The location of other plants or distribution centers of the same company may influence a new facility's location in the network. Issues of product mix and capacity are strongly interconnected to the location decision in this context.

Free trade zone

Free Trade Zones A foreign trade zone or a **free trade zone** is typically a closed facility (under the supervision of the customs department) into which foreign goods can be brought without being subject to the normal customs requirements. There are about 170 such free trade zones in the United States today. Such specialized locations also exist in other countries. Manufacturers in free trade zones can use imported components in the final product and delay payment of customs duties until the product is shipped into the host country.

Political Risk The fast-changing geopolitical scenes in numerous nations present exciting, challenging opportunities. But the extended phase of transformation that many countries are undergoing makes the decision to locate in those areas extremely difficult. Political risks in both the country of location and the host country influence location decisions.

Government Barriers Barriers to enter and locate in many countries are being removed today through legislation. Yet many nonlegislative and cultural barriers should be considered in location planning.

Trading blocs

Trading Blocs The world of **trading blocs** gained a new member with the ratification of the North American Free Trade Agreement (NAFTA). Such agreements influence location decisions, both within and outside trading bloc countries. Firms typically locate, or relocate, within a bloc to take advantage of new market opportunities or lower total costs afforded by the trading agreement. Other companies (those outside the trading bloc countries) decide on locations within the bloc so as not to be disqualified from competing in the new market. Examples include the location of various Japanese auto manufacturing plants in Europe before 1992 as well as recent moves by many communications and financial services companies into Mexico in a post-NAFTA environment.

Environmental Regulation The environmental regulations that impact a certain industry in a given location should be included in the location decision. Besides measurable cost implications, these regulations influence the relationship with the local community.

Host Community The host community's interest in having the plant in its midst is a necessary part of the evaluation process. Local educational facilities and the broader issue of quality of life are also important.

Competitive Advantage An important decision for multinational companies is the nation in which to locate the home base for each distinct business. Porter suggests that a company can have different home bases for distinct businesses or segments. Competitive advantage is created at a home base where strategy is set, the core product and process technology are created, and a critical mass of production takes place. So a company should move its home base to a country that stimulates innovation and provides the best environment for global competitiveness.[1] This concept can also be applied to domestic companies seeking to gain sustainable competitive advantage. It partly explains the southeastern states' recent emergence as the preferred corporate destination within the United States (that is, their business climate fosters innovation and low-cost production).

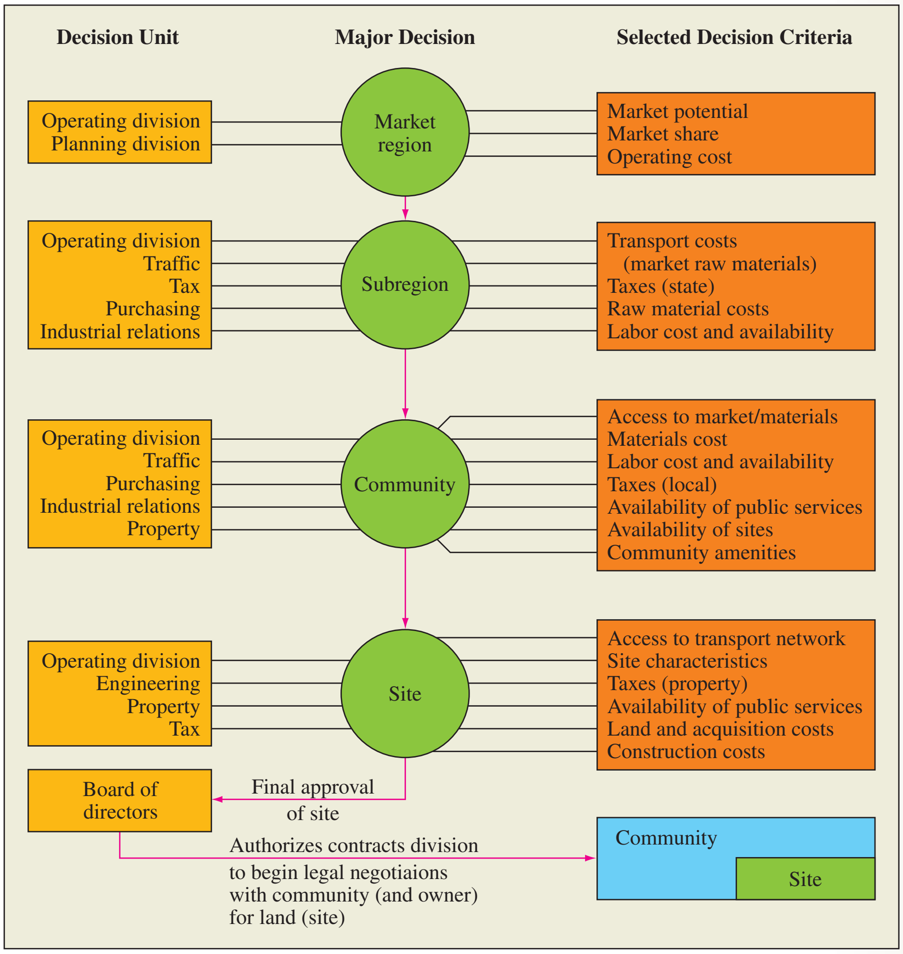
Global

PLANT LOCATION METHODS

"If the boss likes Bakersfield, I like Bakersfield." Exhibit TN10.1 summarizes the set of decisions that a company must make in choosing a plant location. Although the exhibit implies a step-by-step process, virtually all activities listed take place simultaneously.

EXHIBIT TN10.1

Plant Search: Company XYZ



SOURCE: T. M. CARROLL AND R. D. DEAN, "A BAYESIAN APPROACH TO PLANT-LOCATION DECISIONS," *DECISION SCIENCES* 11, NO. 1 (JANUARY 1980), P. 87. COPYRIGHT © 1980 DECISION SCIENCES. REPRINTED BY PERMISSION OF DECISION SCIENCES INSTITUTE, LOCATED AT GEORGIA STATE UNIVERSITY, ATLANTA, GA.

As suggested by the preceding vote for Bakersfield, political decisions may occasionally override systematic analysis.

Evaluation of alternative regions, subregions, and communities is commonly termed *macro analysis.* Evaluation of specific sites in the selected community is termed *micro analysis.* Techniques used to support macro analyses include factor-rating systems, linear programming, and centroid method. A detailed cost analysis would accompany each of these methods, and they must, of course, be related to business strategy.

FACTOR-RATING SYSTEMS

Factor-rating systems

Factor-rating systems are perhaps the most widely used of the general location techniques because they provide a mechanism to combine diverse factors in an easy-to-understand format.

By way of example, a refinery assigned the following range of point values to major factors affecting a set of possible sites:

	RANGE
Fuels in region	0 to 330
Power availability and reliability	0 to 200
Labor climate	0 to 100
Living conditions	0 to 100
Transportation	0 to 50
Water supply	0 to 10
Climate	0 to 50
Supplies	0 to 60
Tax policies and laws	0 to 20

Each site was then rated against each factor, and a point value was selected from its assigned range. The sums of assigned points for each site were then compared. The site with the most points was selected.

A major problem with simple point-rating schemes is that they do not account for the wide range of costs that may occur within each factor. For example, there may be only a few hundred dollars' difference between the best and worst locations on one factor and several thousands of dollars' difference between the best and the worst on another. The first factor may have the most points available to it but provide little help in making the location decision; the second may have few points available but potentially show a real difference in the value of locations. To deal with this problem, it has been suggested that points possible for each factor be derived using a weighting scale based on standard deviations of costs rather than simply total cost amounts. In this way, relative costs can be considered.

TRANSPORTATION METHOD OF LINEAR PROGRAMMING

Transportation method

The **transportation method** is a special linear programming method. (Note that linear programming is developed in detail in Supplement A.) It gets its name from its application to problems involving transporting products from several sources to several destinations. The two common objectives of such problems are either (1) minimize the cost of shipping n units to m destinations or (2) maximize the profit of shipping n units to m destinations.

Interactive Operations Management

EXAMPLE TN10.1: U.S. Pharmaceutical Company

Suppose the U.S. Pharmaceutical Company has four factories supplying the warehouses of four major customers and its management wants to determine the minimum-cost shipping schedule for its monthly output to these customers. Factory supply, warehouse demands, and shipping costs per case for these drugs are shown in Exhibit TN10.2.

EXHIBIT TN10.2

Data for U.S. Pharmaceutical Transportation Problem

					Shipping Costs per Case (in Dollars)			
Factory	Supply	Warehouse	Demand	From	To Columbus	To St. Louis	To Denver	To Los Angeles
Indianapolis	15	Columbus	10	Indianapolis	$25	$35	$36	$60
Phoenix	6	St. Louis	12	Phoenix	55	30	25	25
New York	14	Denver	15	New York	40	50	80	90
Atlanta	11	Los Angeles	9	Atlanta	30	40	66	75

EXHIBIT TN10.3

Transportation Matrix for U.S. Pharmaceutical Problem

From \ To	Columbus	St. Louis	Denver	Los Angeles	Factory supply
Indianapolis	25	35	36	60	15
Phoenix	55	30	25	25	6
New York	40	50	80	90	14
Atlanta	30	40	66	75	11
Destination requirements	10	12	15	9	46 / 46

The transportation matrix for this example appears in Exhibit TN10.3, where supply availability at each factory is shown in the far right column and the warehouse demands are shown in the bottom row. The shipping costs are shown in the small boxes within the cells. For example, the cost to ship one unit from the Indianapolis factory to the customer warehouse in Columbus is $25.

SOLUTION

This problem can be solved by using Microsoft Excel's Solver function. Exhibit TN10.4 shows how the problem can be set up in the spreadsheet. Cells B6 through E6 contain the requirement for each customer warehouse. Cells F2 through F5 contain the amount that can be supplied from each plant. Cells B2 through E5 are the cost of shipping one unit for each potential plant and warehouse combination.

Cells for the solution of the problem are B9 through E12. These cells can initially be left blank when setting up the spreadsheet. Column cells F9 through F12 are the sum of each row indicating how much is actually being shipped from each factory in the candidate solution. Similarly, row cells B13 through E13 are sums of the amount being shipped to each customer in the candidate solution. The Excel Sum function can be used to calculate these values.

The cost of the candidate solution is calculated in cells B16 through E19. Multiplying the amount shipped in the candidate solution by the cost per unit of shipping over that particular route makes this calculation. For example, multiplying B2 by B9 in cell B16 gives the cost of shipping between Indianapolis and Columbus for the candidate solution. The total cost shown in cell F20 is the sum of all these individual costs.

To solve the problem the Excel Solver application needs to be accessed. The Solver is found by selecting Tools and then Solver from the Excel menu. A screen similar to what is shown below should appear. If you cannot find Solver at that location, the required add-in might not have been added when

EXHIBIT TN10.4

Excel Screen Showing the U.S. Pharmaceutical Problem

Microsoft Excel - US Pharmaceutical.xls

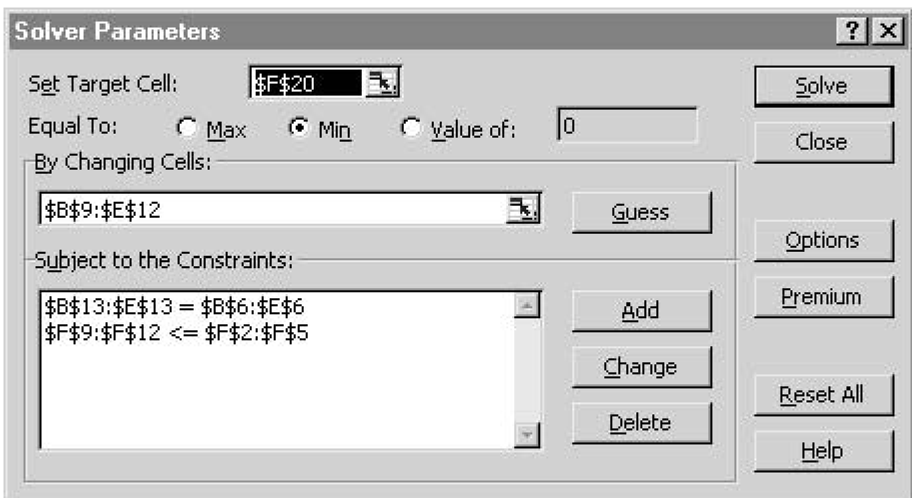
F20 = =SUM(B16:E19)

	A	B	C	D	E	F
1	**From/To**	Columbus	St. Louis	Denver	Los Angeles	**Factory Supply**
2	Indianapolis	25	35	36	60	15
3	Phoenix	55	30	25	25	6
4	New York	40	50	80	90	14
5	Atlanta	30	40	66	75	11
6	**Requirements**	10	12	15	9	
7						
8	**Candidate Solution**					**Total Shipped**
9	Indianapolis	0	0	15	0	15
10	Phoenix	0	0	0	6	6
11	New York	10	4	0	0	14
12	Atlanta	0	8	0	3	11
13	**Total Supplied**	10	12	15	9	
14						
15	**Cost Calculations**					
16	Indianapolis	0	0	540	0	
17	Phoenix	0	0	0	150	
18	New York	400	200	0	0	
19	Atlanta	0	320	0	225	
20					**Total Cost**	$1,835
21						

US Pharmaceutical

Ready NUM

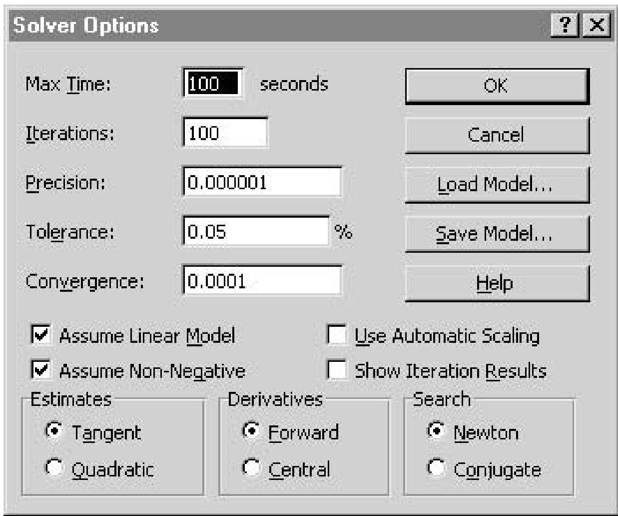
Excel was initially installed on your computer. Solver can easily be added if you have your original Excel installation disk.



Solver parameters now need to be set. First set the target cell. This is the cell where the total cost associated with the solution is calculated. In our sample problem this is cell F20. Next we need to indicate that we are minimizing this cell. Selecting the "Min" button does this. The location of our solution is indicated in the "Changing Cells." These cells are B9 through E12 in our example.

Next we need to indicate the constraints for our problem. For our transportation problem we need to be sure that customer demand is met and that we do not exceed the capacity of our manufacturing plants. To ensure that demand is met, click on "Add" and highlight the range of cells where we have calculated the total amount being shipped to each customer. This range is B13 to E13 in our example. Next select "=" indicating that we want the amount shipped to equal demand. Finally, on the right side enter the range of cells where the actual customer demand is stated in our spreadsheet. This range is B6 to E6 in our example.

The second set of constraints that ensures that the capacity of our manufacturing plants is not exceeded is entered similarly. The range of cells that indicated how much is being shipped from each factory is F9 to F12. These values need to be less than or equal to (<=) the capacity of each factory, which is in cells F2 to F5. To set up the Solver, a few options need to be set as well. Click on the "Options" button and the following screen should appear:



Two options need to be set for solving transportation problems. First we need "Assume Linear Model." This tells the Solver that there are no nonlinear calculations in our spreadsheet. This is important because the Solver can use a very efficient algorithm to calculate the optimal solution to this problem if this condition exists. Next the "Assume Non-Negative" box needs to be checked. This tells Solver that the values in our solution need to be greater than or equal to zero. In transportation problems shipping negative quantities does not make any sense. Click "OK" to return to the main Solver box, and then click "Solve" to actually solve the problem. Solver will notify you that it found a solution. Indicate that you want that solution saved. Finally, click OK to go back to the main spreadsheet. The solution should be in cells B9 to E12.

The transportation method can be used to solve many different types of problems if it is applied innovatively. For example, it can be used to test the cost impact of different candidate locations on the entire production–distribution network. To do this we might add a new row that contains the unit shipping cost from a factory in a new location, say, Dallas, to the existing set of customer warehouses, along with the total amount it could supply. We could then solve this particular matrix for minimum total cost. Next we would replace the factory located in Dallas in the same row of the matrix with a factory at a different location, Houston, and again solve for minimum total cost. Assuming the factories in Dallas and Houston would be identical in other important respects, the location resulting in the lowest total cost for the network would be selected.

For additional information about using the Solver, see Supplement A, "Linear Programming with the Excel Solver." ●

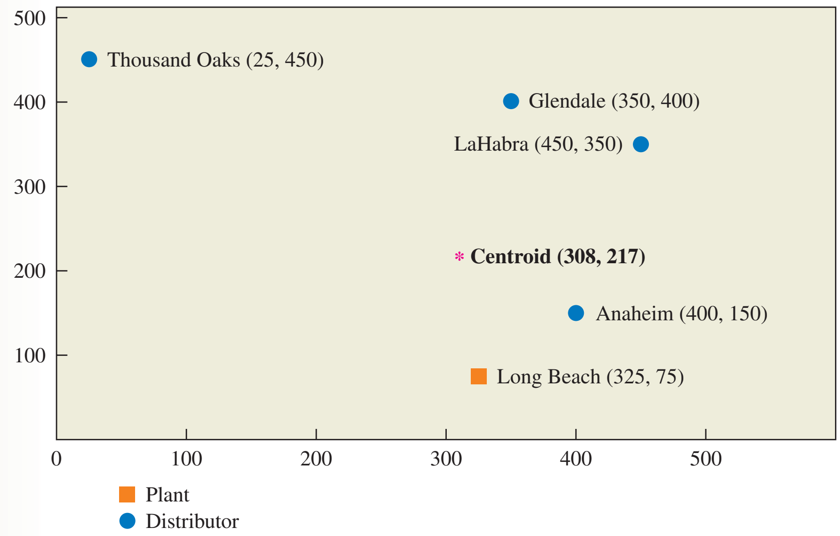
CENTROID METHOD

The **centroid method** is a technique for locating single facilities that considers the existing facilities, the distances between them, and the volumes of goods to be shipped. The technique is often used to locate intermediate or distribution warehouses. In its simplest form, this

Centroid method

EXHIBIT TN10.5

Grid Map for Centroid Example



method assumes that inbound and outbound transportation costs are equal, and it does not include special shipping costs for less than full loads.

Another major application of the centroid method today is the location of communication towers in urban areas. Examples include radio, TV, and cell phone towers. In this application the goal is to find sites that are near clusters of customers, thus ensuring clear radio signals.

The centroid method begins by placing the existing locations on a coordinate grid system. The choice of coordinate systems is entirely arbitrary. The purpose is to establish relative distances between locations. Using longitude and latitude coordinates might be helpful in international decisions. Exhibit TN10.5 shows an example of a grid layout.

The centroid is found by calculating the *X* and *Y* coordinates that result in the minimal transportation cost. We use the formulas

$$C_x = \frac{\sum d_{ix} V_i}{\sum V_i} \qquad C_y = \frac{\sum d_{iy} V_i}{\sum V_i}$$

where

$C_x = X$ coordinate of the centroid
$C_y = Y$ coordinate of the centroid
$d_{ix} = X$ coordinate of the ith location
$d_{iy} = Y$ coordinate of the ith location
$V_i =$ Volume of goods moved to or from the ith location

EXAMPLE TN10.2: HiOctane Refining Company

The HiOctane Refining Company needs to locate an intermediate holding facility between its refining plant in Long Beach and its major distributors. Exhibit TN10.5 shows the coordinate map. The amount of gasoline shipped to or from the plant and distributors appears in Exhibit TN10.6.

In this example, for the Long Beach location (the first location), $d_{1x} = 325$, $d_{1y} = 75$, and $V_1 = 1{,}500$.

SOLUTION

Using the information in Exhibits TN10.5 and TN10.6, we can calculate the coordinates of the centroid:

$$C_x = \frac{(325 \times 1{,}500) + (400 \times 250) + (450 \times 450) + (350 \times 350) + (25 \times 450)}{1{,}500 + 250 + 450 + 350 + 450}$$

$$= \frac{923{,}750}{3{,}000} = 307.9$$

EXHIBIT TN10.6

Shipping Volumes, Centroid Example

LOCATIONS	GALLONS OF GASOLINE PER MONTH (000,000)
Long Beach	1,500
Anaheim	250
LaHabra	450
Glendale	350
Thousand Oaks	450

$$C_y = \frac{(75 \times 1{,}500) + (150 \times 250) + (350 \times 450) + (400 \times 350) + (450 \times 450)}{1{,}500 + 250 + 450 + 350 + 450}$$

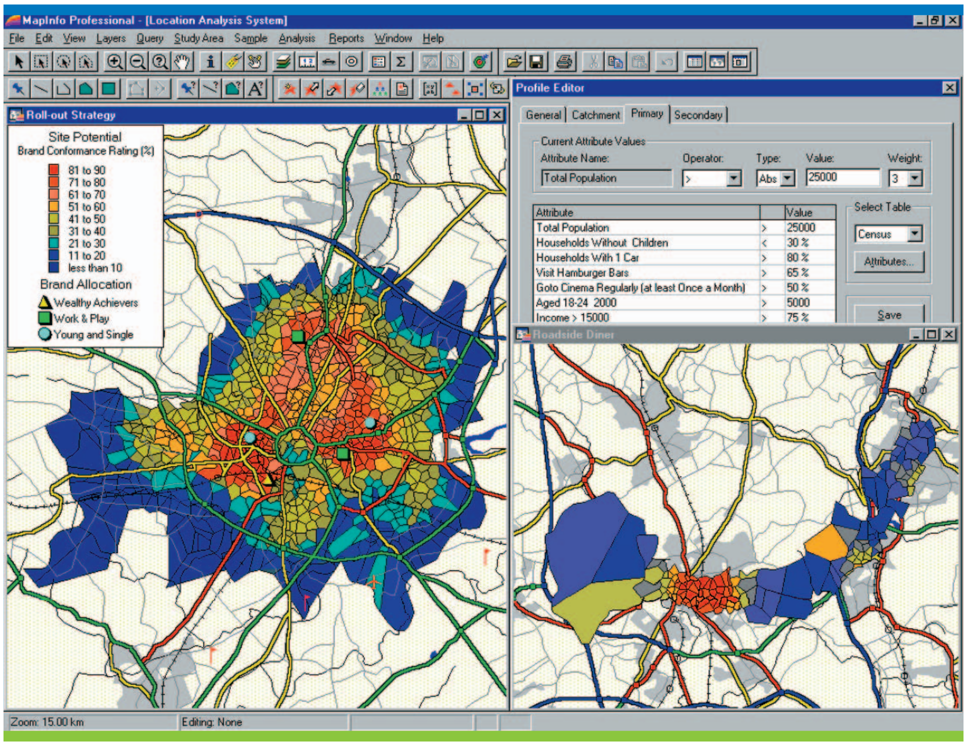
$$= \frac{650{,}000}{3{,}000} = 216.7$$

This gives management the X and Y coordinates of approximately 308 and 217, respectively, and provides an initial starting point to search for a new site. By examining the location of the calculated centroid on the grid map, we can see that it might be more cost-efficient to ship directly between the Long Beach plant and the Anaheim distributor than to ship via a warehouse near the centroid. Before a location decision is made, management would probably recalculate the centroid, changing the data to reflect this (that is, decrease the gallons shipped from Long Beach by the amount Anaheim needs and remove Anaheim from the formula).

LOCATING SERVICE FACILITIES

Because of the variety of service firms and the relatively low cost of establishing a service facility compared to one for manufacturing, new service facilities are far more common than new factories and warehouses. Indeed, there are few communities in which rapid population growth has not been paralleled by concurrent rapid growth in retail outlets, restaurants, municipal services, and entertainment facilities.

LESS THAN TWO MILES FROM TWIN CITIES INTERNATIONAL AIRPORT, WITH FOUR MAJOR HIGHWAYS INTERSECTING THE 78-ACRE PROPERTY, BLOOMINGTON'S MALL OF AMERICA HAS BECOME GLOBALLY RECOGNIZED AS THE LARGEST ENTERTAINMENT AND RETAIL COMPLEX IN THE UNITED STATES. SERVING OVER 28 MILLION PEOPLE WITHIN ONE-DAY DRIVE AS WELL AS MANY MORE AS A DESTINATION, THE MALL EMPLOYS MORE THAN 12,000 PEOPLE AND TOTAL TRAFFIC IS BETWEEN 35 AND 42 MILLION VISITS YEARLY. VISITORS SPEND AN AVERAGE OF 3 HOURS IN THE MALL, WHICH IS THREE TIMES THE NATIONAL AVERAGE FOR SHOPPING MALLS.



GEOGRAPHIC INFORMATION SYSTEMS (GIS), SHOWN HERE FROM MAPINFO, ARE USED BY RETAILERS, FINANCIAL SERVICES GROUPS, AND OTHERS IN THE SITE SELECTION PROCESS. MAPPING INFORMATION ON POTENTIAL SITES SUCH AS DEMOGRAPHICS, COMPETITORS, AND SO ON ALLOWS INFORMATION TO BE SEEN IN A SINGLE, COMPREHENSIVE VIEW FOR MORE INFORMED DECISION MAKING.

Services typically have multiple sites to maintain close contact with customers. The location decision is closely tied to the market selection decision. If the target market is college-age groups, locations in retirement communities—despite desirability in terms of cost, resource availability, and so forth—are not viable alternatives. Market needs also affect the number of sites to be built and the size and characteristics of the sites. Whereas manufacturing location decisions are often made by minimizing costs, many service location decision techniques maximize the profit potential of various sites. Next we present a multiple regression model that can be used to help select good sites.

EXAMPLE TN10.3: Screening Location Sites at La Quinta Motor Inns

Selecting good sites is crucial to a hotel chain's success. Of the four major marketing considerations (price, product, promotion, and location), location and product have been shown to be most important for multisite firms. As a result, hotel chain owners who can pick good sites quickly have a distinct competitive advantage.

Exhibit TN10.7 shows the initial list of variables included in a study to help La Quinta Motor Inns screen potential locations for its new hotels.[2] Data were collected on 57 existing La Quinta Inns. Analysis of the data identified the variables that correlated with operating profit in 1983 and 1986. (See Exhibit TN10.8.)

SOLUTION

A *regression model* (see Chapter 12) was constructed. Its final form was

$$\begin{aligned}\text{Profitability} = {} & 39.05 - 5.41 \times \text{State population per inn (1,000)} \\ & + 5.86 \times \text{Price of the inn} \\ & - 3.91 \times \text{Square root of the median income of the area (1,000)} \\ & + 1.75 \times \text{College students within four miles}\end{aligned}$$

The model shows that profitability is affected by market penetration, positively affected by price, negatively affected by higher incomes (the inns do better in lower-median-income areas), and positively affected by colleges nearby.

EXHIBIT TN10.7

Independent Variables Collected for the Initial Model-Building Stage

CATEGORY	NAME	DESCRIPTION
Competitive	INNRATE	Inn price
	PRICE	Room rate for the inn
	RATE	Average competitive room rate
	RMS 1	Hotel rooms within 1 mile
	RMSTOTAL	Hotel rooms within 3 miles
	ROOMSINN	Inn rooms
Demand generators	CIVILIAN	Civilian personnel on base
	COLLEGE	College enrollment
	HOSP1	Hospital beds within 1 mile
	HOSPTOTL	Hospital beds within 4 miles
	HVYIND	Heavy industrial employment
	LGTIND	Light industrial acreage
	MALLS	Shopping mall square footage
	MILBLKD	Military base blocked
	MILITARY	Military personnel
	MILTOT	MILITARY + CIVILIAN
	OFC1	Office space within 1 mile
	OFCTOTAL	Office space within 4 miles
	OFCCBD	Office space in Central Business District
	PASSENGR	Airport passengers enplaned
	RETAIL	Scale ranking of retail activity
	TOURISTS	Annual tourists
	TRAFFIC	Traffic count
	VAN	Airport van
Demographic	EMPLYPCT	Unemployment percentage
	INCOME	Average family income
	POPULACE	Residential population
Market awareness	AGE	Years inn has been open
	NEAREST	Distance to nearest inn
	STATE	State population per inn
	URBAN	Urban population per inn
Physical	ACCESS	Accessibility
	ARTERY	Major traffic artery
	DISTCBD	Distance to downtown
	SIGNVIS	Sign visibility

EXHIBIT TN10.8

A Summary of the Variables That Correlated with Operating Margin in 1983 and 1986

VARIABLE	1983	1986
ACCESS	.20	
AGE	.29	.49
COLLEGE		.25
DISTCBD		−.22
EMPLYPCT	−.22	−.22
INCOME		−.23
MILTOT		.22
NEAREST	−.51	
OFCCBD	.30	
POPULACE	.30	.35
PRICE	.38	.58
RATE		.27
STATE	−.32	−.33
SIGNVIS	.25	
TRAFFIC	.32	
URBAN	−.22	−.26

La Quinta implemented the model on a spreadsheet and routinely uses the spreadsheet to screen potential real estate acquisitions. The founder and president of La Quinta has accepted the model's validity and no longer feels obligated to personally select the sites.

This example shows that a specific model can be obtained from the requirements of service organizations and used to identify the most important features in site selection.

CONCLUSION

Facility location decisions are a key element in any firm's overall strategic plan. Dramatic changes in the global geopolitical environment, coupled with rapid advances in technology, have placed a premium on making location decisions in a matter of weeks rather than months, as has been the case in the recent past. As a final comment, much of the location "action" is in deciding where to locate support functions rather than factories or retail outlets. In these situations the need for special capabilities of the workforce is often far more important than other cost factors. For example, IBM Business Consulting Services stated that a dominant factor in deciding where to locate the software application group of its client, a U.S. investment bank, was the availability of a large pool of multilingual workers.

KEY TERMS

Free trade zones A closed facility (under the supervision of government customs officials) into which foreign goods can be brought without being subject to the payment of normal import duties.

Trading bloc A group of countries that agrees on a set of special arrangements governing the trading of goods between member countries. Companies may locate in places affected by the agreement to take advantage of new market opportunities.

Factor-rating system An approach for selecting a facility location by combining a diverse set of factors. Point scales are developed for each criterion. Each potential site is then evaluated on each criterion and the points are combined to calculate a rating for the site.

Transportation method A special linear programming method that is useful for solving problems involving transporting products from several sources to several destinations.

Centroid method A technique for locating single facilities that considers the existing facilities, the distances between them, and the volumes of goods to be shipped.

FORMULA REVIEW

Centroid

$$C_x = \frac{\sum d_{ix} V_i}{\sum V_i} \qquad C_y = \frac{\sum d_{iy} V_i}{\sum V_i}$$

SOLVED PROBLEM

SOLVED PROBLEM 1

Cool Air, a manufacturer of automotive air conditioners, currently produces its XB-300 line at three different locations: Plant A, Plant B, and Plant C. Recently management decided to build all compressors, a major product component, in a separate dedicated facility, Plant D.

Using the centroid method and the information displayed in Exhibits TN10.9 and TN10.10, determine the best location for Plant D. Assume a linear relationship between volumes shipped and shipping costs (no premium charges).

Solution

$$d_{1x} = 150 \qquad d_{1y} = 75 \qquad V_1 = 6{,}000$$

$$d_{2x} = 100 \qquad d_{2y} = 300 \qquad V_2 = 8{,}200$$

$$d_{3x} = 275 \qquad d_{3y} = 380 \qquad V_3 = 7{,}000$$

$$C_x = \frac{\sum d_{ix} V_i}{\sum V_i} = \frac{(150 \times 6{,}000) + (100 \times 8{,}200) + (275 \times 7{,}000)}{6{,}000 + 8{,}200 + 7{,}000} = 172$$

EXHIBIT TN10.9

Plant Location Matrix

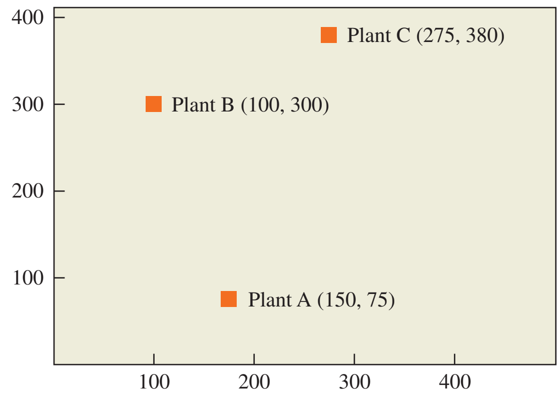


EXHIBIT TN10.10

Quantity of Compressors Required by Each Plant

PLANT	COMPRESSORS REQUIRED PER YEAR
A	6,000
B	8,200
C	7,000

$$C_y = \frac{\sum d_{iy} V_i}{\sum V_i} = \frac{(75 \times 6{,}000) + (300 \times 8{,}200) + (380 \times 7{,}000)}{21{,}200} = 262.7$$

Plant D$[C_x, C_y]$ = D[172, 263]

REVIEW AND DISCUSSION QUESTIONS

1 What motivations typically cause firms to initiate a facilities location or relocation project?
2 List five major reasons why a new electronic components manufacturing firm should move into your city or town.
3 How do facility location decisions differ for service facilities and manufacturing plants?
4 What are the pros and cons of relocating a small or midsized manufacturing firm (that makes mature products) from the United States to Mexico in the post-NAFTA environment?
5 If you could locate your new software development company anywhere in the world, which place would you choose, and why?

PROBLEMS

1 Refer to the information given in the solved problem. Suppose management decides to shift 2,000 units of production from Plant B to Plant A. Does this change the proposed location of Plant D, the compressor production facility? If so, where should Plant D be located?

1. $C_x = 176.7$
$C_y = 241.5$

2 A small manufacturing facility is being planned that will feed parts to three heavy manufacturing facilities. The locations of the current plants with their coordinates and volume requirements are given in the following table:

2. $C_x = 374.$
$C_y = 357.$

PLANT LOCATION	COORDINATES (x, y)	VOLUME (PARTS PER YEAR)
Peoria	300, 320	4,000
Decatur	375, 470	6,000
Joliet	470, 180	3,000

Use the centroid method to determine the best location for this new facility.

3 Bindley Corporation has a one-year contract to supply motors for all washing machines produced by Rinso Ltd. Rinso manufactures the washers at four locations around the country: New York, Fort Worth, San Diego, and Minneapolis. Plans call for the following numbers of

3. See ISM.

Total profit = $4,240,000.

0	0	0	10
50	0	50	0
0	70	10	70

or

0	0	0	10
50	50	0	0
0	20	60	70

Alternate optimal solutions.

washing machines to be produced at each location:

New York	50,000
Fort Worth	70,000
San Diego	60,000
Minneapolis	80,000

Bindley has three plants that can produce the motors. The plants and production capacities are

Boulder	100,000
Macon	100,000
Gary	150,000

Due to varying production and transportation costs, the profit Bindley earns on each 1,000 units depends on where they were produced and where they were shipped. The following table gives the accounting department estimates of the dollar profit per unit. (Shipment will be made in lots of 1,000.)

	Shipped To			
Produced At	New York	Fort Worth	San Diego	Minneapolis
Boulder	7	11	8	13
Macon	20	17	12	10
Gary	8	18	13	16

Given profit maximization as a criterion, Bindley would like to determine how many motors should be produced at each plant and how many motors should be shipped from each plant to each destination.

a. Develop a transportation grid for this problem.

b. Find the optimal solution using Microsoft Excel.

4. See ISM.

4 Rent'R Cars is a multisite car rental company in the city. It is trying out a new "return the car to the location most convenient for you" policy to improve customer service. But this means that the company has to constantly move cars around the city to maintain required levels of vehicle availability. The supply and demand for economy cars, and the total cost of moving these vehicles between sites, are shown below.

From \ To	*D*	*E*	*F*	*G*	Supply
A	$9	$8	$6	$5	50
B	9	8	8	0	40
C	5	3	3	10	75
Demand	50	60	25	30	165 / 165

a. Find the solution that minimizes moving costs using Microsoft Excel.

b. What would you have to do to the costs to assure that *A* always sends a car to *D* as part of the optimal solution?

CASE: APPLICHEM—THE TRANSPORTATION PROBLEM

Applichem management is faced with the difficult problem of allocating to its customers the capacity of manufacturing plants that are located around the world. Management has long recognized that the manufacturing plants differ greatly in efficiency but has had little success in improving the operations of the inefficient plants. At this time, management has decided to focus on how best to use the capacity of its plants given the differences in manufacturing costs that currently exist. They recognize that this study may result in the significant reduction of output or possibly the shutting down of one or more of the existing plants.

Applichem makes a product called Release-ease. Plastics molding manufacturers use this chemical product. Plastic parts are made by injecting hot plastic into a mold made in the shape of the part. After the plastic has sufficiently cooled, the fresh part is removed from the mold and the mold is then reused to make subsequent parts. Release-ease is a dry powder, applied as part of the manufacturing process, that makes it easy to remove the part from the mold.

Applichem has made the product since the early 1950s, and demand has been consistent over time. A recent study by Applichem's market research team has indicated that demand for Release-ease should be fairly steady for the next five years. Although Applichem does have some competition, particularly in the European markets, management feels that as long as they can provide a quality product at a competitive cost, customers should stick with Applichem. Release-ease sells at an average price of $1.00 per pound.

The company owns plants capable of making Release-ease in the following cities: Gary, Indiana; Windsor, Ontario, Canada; Frankfurt, Germany; Mexico City, Mexico; Caracas, Venezuela; and Osaka, Japan. Although the plants are focused on meeting demand for the immediate surrounding regions, there is considerable exporting and importing of product for various reasons. The following table contains data on how demand has been met during the past year:

PRODUCT MADE AND SHIPPED DURING PAST YEAR (×100,000 POUNDS)

FROM/TO	MEXICO	CANADA	VENEZUELA	EUROPE	UNITED STATES	JAPAN
Mexico City	3.0		6.3			7.9
Windsor, Ontario		2.6				
Caracas			4.1			
Frankfurt			5.6	20.0	12.4	
Gary					14.0	
Osaka						4.0

Differences in the technologies used in the plants and in local raw material and labor costs created significant differences in the cost to produce Release-ease in the various locations. These costs may change dramatically due to currency valuation and labor law changes in some of the countries. This is especially true in Mexico and Venezuela. The capacity of each plant also differs at each location, and management has no interest in increasing capacity anywhere at this time. The following table gives details on the costs to produce and capacity of each plant:

PLANT PRODUCTION COSTS AND CAPACITY

PLANT	PRODUCTION COST (PER 1,000 LBS)	PLANT CAPACITY (×100,000 LBS)
Mexico City	95.01	22.0
Windsor, Ontario	97.35	3.7
Caracas	116.34	4.5
Frankfurt	76.69	47.0
Gary	102.93	18.5
Osaka	153.80	5.0

In considering how best to use the capacity of its plants, Applichem management needs to consider the cost of shipping product from one customer region to another. Applichem now commonly ships product in bulk around the world, but it is expensive. The costs involved are not only the transportation costs but also import duties that are assessed by customs in some countries. Applichem is committed to meeting demand, though, and sometimes this is done even though profit might not be made on all orders.

The following table details the demand in each country, the cost to transport product from each plant to each country, and the current import duty rate levied by each country. (These percentages do not reflect current duties.) Import duty is calculated on the approximate production plus transportation cost of product brought into the country. (For example, if the production and shipping cost for 1,000 pounds of Release-ease shipped into Venezuela were $100, the import duty would be $100 × .5 = $50.)

TRANSPORTATION COST (PER 1,000 LBS), IMPORT DUTIES, AND DEMANDS FOR RELEASE-EASE

PLANT/COUNTRY	MEXICO	CANADA	VENEZUELA	EUROPE	UNITED STATES	JAPAN
Mexico City	0	11.40	7.00	11.00	11.00	14.00
Windsor, Ontario	11.00	0	9.00	11.50	6.00	13.00
Caracas	7.00	10.00	0	13.00	10.40	14.30
Frankfurt	10.00	11.50	12.50	0	11.20	13.30
Gary	10.00	6.00	11.00	10.00	0	12.50
Osaka	14.00	13.00	12.50	14.20	13.00	0
Total demand (×100,000 lbs)	3.0	2.6	16.0	20.0	26.4	11.9
Import duty	0.0%	0.0%	50.0%	9.5%	4.5%	6.0%

QUESTIONS

Given all these data, set up a spreadsheet (Applichem.xls is a start) and answer the following questions for management:

1 Evaluate the cost associated with the way Applichem's plant capacity is currently being used.
2 Determine the optimal use of Applichem's plant capacity using the Solver in Excel.
3 What would you recommend that Applichem management do? Why?

SOURCE: THIS CASE IS ROUGHLY BASED ON DATA CONTAINED IN "APPLICHEM (A)," HARVARD BUSINESS SCHOOL, 9-685-051.

CASE: THE PLANT LOCATION PUZZLE[3]

Ann Reardon made her way across the crowded tradeshow floor, deep in thought and oblivious to the noisy activity all around her. As CEO of the Eldora Company (EDC) for the previous 13 years, she had led her organization through a period of extraordinary success. While larger bicycle makers had moved their manufacturing operations overseas to take advantage of lower labor costs, Eldora had stuck with a domestic manufacturing strategy, keeping its plant on the same campus as its corporate offices in Boulder, Colorado. Ann felt that her strategy of keeping all the parts of the company in the same location, although unconventional, had contributed greatly to cooperation among various departments and, ultimately, to the company's growth: EDC had become the largest and most profitable bicycle company in the United States. Yet her manufacturing vice president, Sean Andrews, was now urging her to build a plant in China.

"Look at the number of companies here," he had said that morning, as they helped several other EDC staffers stack brochures on the exhibit table and position the company's latest models around the perimeter of their area. Manufacturing heads rarely attended trade shows; in fact, this was Sean's first, but he had wanted to attend, and Ann had supported his interest. "There are too many players in this market," he had said. "I've been saying this for two months now, and you know the forecasters' numbers back me up. But if they weren't enough to convince you, just look around. The industry is reaching the saturation point here in the States. We have to break into Asia."

"Leave it alone, Sean," Ann had replied. "I know this is something you're pushing; you've said so in the past. But let's set up a time to talk about it in detail later. This isn't the time or the place."

Now, three hours later, with the show in full swing, Ann understood why Sean had been compelled to speak up again. Having all their competitors in the same room at the same time was a powerful visual reminder of how the industry had changed. She thought about what Sean had said about the U.S. market. In 1992 EDC's sales and earnings had hit record levels. The company now produced almost 30 percent of the bicycles sold in the United States. U.S. mass-market bicycle sales were growing by only 2 percent per year, while the Asian market for those same bikes was nearly doubling annually. And Eldora could not competitively serve those markets from its U.S. manufacturing facility. Two of the largest bike manufacturers in the world, located in rapidly growing Asian markets, enjoyed a significant labor and distribution cost advantage.

She stopped at a mountain bike display set up by a fast-growing young bike company. Mountain bikes with front suspension were the latest trend—the added support and cushion allowed riders to better absorb the shocks inherent in off-road riding without slowing down or losing balance. Most of these bikes were still prohibitively expensive. But Eldora, too, had an entry in this product category, retailing for about $190, and Ann was proud of it. For years, the company had concentrated its efforts on inexpensive bicycles, which retailed through mass merchandisers for between $100 and $200. Eldora's prices were slightly higher than other low-end competitors, but large retailers were willing to pay the premium because EDC had consistently been able to offer many state-of-the-art styles and features with quick, timely deliveries that competitors building overseas couldn't match.

One of the reasons the company had been so successful was that Boulder, Colorado, was a bicyclists' mecca. Eldora employees at all levels shared a genuine love of bicycling and eagerly pursued knowledge of the industry's latest trends and styles. Someone was always suggesting a better way to position the hand brakes or a new toe grip that allowed for better traction and easier dismounts. And Eldora never had a shortage of people willing to test out the latest prototypes.

Another reason was that all marketing staff, engineers, designers, and manufacturing personnel worked on one campus, within a 10-minute walk of one another. Ann had bet big on that strategy, and it had paid off. Communication was easy, and changes in styles, production plans, and the like could be made quickly and efficiently. Mountain bikes, for example, had gone from 0 percent to more than 50 percent of the market volume since 1988, and Eldora had met the increased demand with ease. And when orders for cross-bikes—a mountain/road bike hybrid that had enjoyed a spurt of popularity—began to fall off, Eldora had been able to adjust its production run with minimal disruption.

EDC had also benefited from its foray into the high-end market (bicycles retailing for between $400 and $700) 12 years earlier. One of Ann's first moves as CEO had been to enter into a joint venture with Rinaldi, a high-end Italian bicycle manufacturer that at the time was specializing in racing models. As part of the agreement, EDC had begun importing Rinaldi bikes under the brand name Summit and selling them through specialty bike dealers. Similarly, Rinaldi had begun marketing EDC bikes in Europe. That arrangement had had lasting rewards: Although racing bikes were no longer very popular, EDC's offerings had taken off. About 20 percent of EDC's sales were now made outside the United States (primarily in Europe and Canada) through this and other agreements.

The relationships with Rinaldi and the specialty bike shops also helped keep EDC management aware of the latest industry trends over the years. Most recently, those trends had included a move toward more exotic frame materials like aluminum and carbon fiber and more advanced components, including the new front-fork suspension systems. Ann examined another rival's brochure touting a soon-to-be-released high-end model with these advances. EDC engineers were clearly ahead of the curve.

Her satisfaction was quickly tempered with thoughts of foreign sales performance. Between 1987 and 1991, EDC's foreign sales had grown at an annual rate of over 80 percent. But during the previous two years they had been flat.

Sean appeared at Ann's side, jolting her out of her thoughts and into the reality of her surroundings. "Dale just finished up the first round of retailers' meetings," he said. "We'd like to get some lunch back over at the hotel and talk about our options." Dale Stewart was Eldora's marketing vice president. His views of what was best for the company often differed from Sean's, but the two had an amiable working relationship and enjoyed frequent spirited verbal sparring matches.

"You won't let this go, will you," Ann said, throwing up her hands in a gesture of surrender. "Fine, let's talk. But you know I won't make a decision until we've had a more formal round of discussions back in Boulder next month."

Over sandwiches, Sean made his case. "Our primary markets in North America and western Europe represent less than a quarter of the worldwide demand. Of the 200 million bicycles made in the world last year, 40 million were sold in China, 30 million in India, and 9 million in Japan. Historically, bikes sold in Asia's developing markets were low-end products used as primary modes of transportation. But the economic picture is changing fast. There's a growing middle class. Suddenly people have disposable income. Many consumers there are now seeking higher quality and trendier styles. Mountain bikes with suspension are in. And cross-bikes are still holding their own. In fact, the demand in these markets for the product categories we produce has been doubling annually, and the growth rates seem sustainable.

"If we're going to compete in Asia, though, we need a local plant. My staff has evaluated many locations there. We've looked at wage rates, proximity to markets, and materials costs, and we feel that China is our best bet. We'd like to open a plant there as soon as possible, and start building our position."

Dale jumped in. "Two of our largest competitors, one from China, one from Taiwan, have been filling the demand so far," he said. "In 1990, 97 percent of the volume produced by these companies was for export. In 1994, they are projecting that 45 percent of their production will be for local markets. We can't compete with them from here. About 20 percent of our product cost is labor, and the hourly wages of the manufacturing workforce in these countries are between 5 percent and 15 percent of ours. It also costs us an additional 20 percent in transportation and duties to get our bicycles to these markets."

He glanced at Sean quickly and continued. "But here's where I disagree with Sean. I think we need a short-term solution. These companies have a big lead on us, and the more I think about it, the more I believe we need to put a direct sales operation in Asia first."

"Dale, you're crazy," Sean said, pouring himself some ice water from the pitcher on the table. "What good would an Asian sales operation do without a manufacturing plant? I know we source components in Asia now, but we could save another 10 percent of those parts if we were located there. Then we would really be bringing Eldora to Asia. If we want to compete there, we have to play from our greatest strength—quality. If we did it your way, you wouldn't be selling Eldora bikes. You'd just be selling some product with our label on it. You wouldn't get the quality. You wouldn't build the same kind of reputation we have here. It wouldn't really be Eldora. Over the long term, it couldn't work."

"We're building bicycles, not rocket ships," Dale countered. "There are lots of companies in Asia that could provide us with a product very quickly if we gave them our designs and helped them with their production process. We could outsource production in the short term until we made more permanent arrangements." He turned to Ann. "We could even outsource the product permanently, despite what Sean says. What do we know about building and running a plant in China? All I know is we're losing potential share even as we sit here. The trading companies aren't giving our products the attention they deserve, and they also aren't giving us the information we need on the features that consumers in these markets want. A sales operation would help us learn the market even as we're entering it. Setting up a plant first would take too long. We need to be over there now, and opening a sales operation is the quickest way."

Ann cut in. "Dale has a good point, Sean," she said. "We've been successful here in large part because our entire operation is in Boulder, on one site. We've had complete control over our own flexible manufacturing operation, and that's been a key factor in our ability to meet rapid change in the local market. How would we address the challenges inherent in manufacturing in a facility halfway around the world? Would you consider moving there? And for how long?

"Also, think about our other options. If the biggest issue keeping us out of these markets right now is cost, then both of you are ignoring a few obvious alternatives. Right now, only our frame-building operation is automated. We could cut labor costs significantly by automating more processes. And why are you so bent on China? Frankly, when I was there last month touring facilities, a lot of what I saw worried me. You know, that day I was supposed to tour a production facility, there was a power failure. Judging by the reactions of the personnel in the plant the next day, these outages are common. The roads to the facility are in very poor condition. And wastewater and cleaning solvents are regularly dumped untreated into the waterways. We could operate differently if we located there, but what impact would that have on costs?

"Taiwan has a better-developed infrastructure than China. What about making that our Asian base? And I've heard that Singapore offers attractive tax arrangements to new manufacturing operations. Then there's Mexico. It's closer to home, and aside from distribution costs, the wage rates are similar to Asia's and many of the other risks would be minimized. You both feel strongly about this, I know, but this isn't a decision we can make based on enthusiasm." Ann crumpled up her sandwich wrapper and drank the last of her soda. "Let's get back over to the exhibits. I'm attending the IT seminar at 1:30. We'll schedule a formal meeting on this subject soon. I was going to say next month, but how about bumping it up two weeks?"

Walking back to the convention center with Dale and Sean, Ann realized that she wasn't just frustrated because she didn't know which course EDC should pursue. She was concerned that she really didn't know which aspects of the decision were important and which were irrelevant. Should she establish a division in China? If so, which functions should she start with? Manufacturing? Marketing? And what about engineering? Or should she consider a different location? Would China's low labor costs offset problems caused by a poor infrastructure?

Growth had always been vitally important to Eldora, both in creating value to shareholders and in providing a work environment that could attract and retain the most talented people. Now it appeared that Ann would have to choose between continued growth and a domestic-only manufacturing strategy that had served her well. Ann knew the plant location decision she had made years earlier had been critical to the company's success, and she felt the company's next move would be just as crucial.

QUESTIONS

1. What is the competitive environment facing EDC?
2. What are EDC's strengths in manufacturing?
3. Should EDC establish a manufacturing division in Asia?
4. What plan of action would you recommend to Ann Reardon?

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FOOTNOTES

1 M. E. Porter, "The Competitive Advantage of Nation," *Harvard Business Review,* March–April 1990.

2 S. E. Kimes and J. A. Fitzsimmons, "Selecting Profitable Hotel Sites at La Quinta Motor Inn," *Interfaces* 20 (March–April 1990), pp. 12–20.

3 This is a broad top-management–oriented strategy case designed to elicit debate.