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Designing a network of service centers involves a tradeoff between the revenue likely to be generated by providing a high level of service and the cost of operating the service network. The authors develop a procedure for determining the location and design strategies for new services using a modified maximal covering location-allocation model. The network optimization procedure relies on direct assessment of consumer sensitivity to distance and nondistance factors through conjoint analysis and simultaneously determines the network size, location of outlets, price, and operating characteristics.

An Approach to Determining Optimal Locations for New Services

Access to retail outlets is a critical factor in determining patronage. A good location strategy gives a firm strategic advantages that competitors may find difficult to duplicate (Jain and Mahajan 1979). For new types of services the location decision is even more critical, because it is through the location that services are made available to potential users (Brown, Brown, and Craig 1981). In designing a network of new service outlets a firm is forced to trade off the expected revenue with the cost of providing the service. By locating more outlets a firm increases accessibility and hence the overall level of service it can provide. Service also can be improved by increasing the attractiveness of the outlets. However, increasing the attractiveness of the outlets or adding more of them increases the cost of establishing and maintaining the service network and may adversely affect profit unless there is a sufficient increase in service utilization.

We present a procedure for determining the optimal location and design of service networks. The approach is particularly suited for new services and for situations in which there is no direct competition among service outlets. In the most extreme case, consumers must patronize a particular service outlet in order to purchase the innovation. In the more general case there is no direct competition among outlets of different firms. Though there is often competition among providers of different forms of a service, for many services there is no direct competition among service outlets once the consumer has chosen the preferred firm.

Consider, for example, networks of automatic teller machines (ATMs) or health maintenance organizations (HMOs). Banks compete aggressively for consumers. However, once a customer opens an account with a particular bank, he or she uses its ATMs and not those of its competitors. Therefore, a particular bank is primarily interested in how well its ATM network serves the market area with little regard to the location of competitors' ATMs. HMOs compete with other forms of health care providers, but once a consumer has enrolled in a particular HMO plan, competition is no longer relevant. The location of centers is the important factor. Designing a proper service network is critical because accessibility to HMO locations and the quality of service are factors that significantly influence the decision to enroll initially. Similarly, access to a bank's ATM network has been found to influence consumer choice of a bank (Rao and Tibrewala 1985) and is a major element of competition among retail banks.

In the next section we briefly review some of the approaches commonly used for retail siting. We then describe the basic structure of the maximal covering model and develop the network optimization procedure. Finally, we present an example of the model's application along with a conjoint analysis procedure for determining consumer sensitivity to distance and service offerings.

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APPROACHES TO LOCATION MODELING

Given the importance of good locational strategies, several procedures for site selection have been proposed in the literature (see Craig, Ghosh, and McLafferty 1984 for a review). The commonly used checklist and regression methods rely on developing a relationship between the profitability of retail outlets and the characteristics of their locations and trade area by studying the performance of existing stores. Checklist procedures (e.g. Nelson 1958) are generally subjective; regression models use a more formal statistical approach. Regression methods have been used for assessing site profitability for a variety of retail outlets (see, e.g., Cottrell 1973; Lord and Lynds 1981; Olsen and Lord 1979). Though the simplicity of the checklist and regression methods has led to their popularity, they both predict future revenues on the basis of past performance. This feature limits their usefulness in estimating sales for new types of retail establishments.

Spatial interaction models use consumers' relative utility for different stores to estimate sales. Early versions of these models relied primarily on distance and store size to measure the utility of the store (Huff 1964). Market share predictions were found to improve, however, when additional variables such as store image were included (Stanley and Sewall 1976). This finding led to the popularity of the multiplicative competitive interactive (MCI) model proposed by Nakanishi and Cooper (1974). The MCI model has been used in several recent studies to estimate store performance (e.g., Achabal, Gorr, and Mahajan 1982; Ghosh and Craig 1983; Ghosh and McLafferty 1982; Jain and Mahajan 1979). One advantage of the MCI model is that it can incorporate a number of distance and nondistance factors in measuring store utilities. Jain and Mahajan (1979), for example, in their study of food retailing, used consumer evaluations of store image, price, appearance, and service level as well as objective measures of the number of checkout counters, employee composition, location at an intersection, and the availability of credit card services. Though these models are valuable in studying pre-existing types of stores, there are problems in using them to locate new forms of retail outlets.

Spatial interaction models are calibrated by surveying the past shopping pattern of a randomly selected sample of individuals from the planning area. The importance consumers give to distance and nondistance factors affecting store choice is inferred from the survey data. The reliance on past choices to reveal future preferences raises problems in applying the findings to new forms of retailing. First, the new service may represent such a significant departure from past norms that no existing store or stores can be used as a surrogate. Context dependency is another problem. The composition of the choice set over which spatial behavior is observed influences the values of the parameters estimated by these models (Eagle 1984; Fotheringham 1981; Ghosh 1984; Meyer and Eagle 1982). Consequently, results from one study area cannot be expected to hold in other areas. This limitation severely restricts the use of choice models calibrated from one study region to design location strategies in another. Another drawback of spatial interaction models is that the total demand for the service is specified exogenously. Location and outlet characteristics, it is assumed, only affect the pattern of patronage to different outlets. In designing new service networks, however, a critical task is to assess the relationship between locational pattern and service utilization.

One way to overcome the problem of context dependency and nonavailability of surrogate stores is to estimate consumer preferences for different store characteristics using simulated store choice or preference data and conjoint or logit techniques. These techniques enable the location analyst to assess consumer preferences for different attributes of the service outlet as well as sensitivity to travel time (Burnett 1982; Louviere and Woodworth 1983; Parker and Srinivasan 1976; Recker and Schuler 1981). From this information it is possible to estimate the size of the retail trade area at different locations and examine the impact of changes in location and outlet design on the trade area.

NETWORK OPTIMIZATION MODEL

Once the relationship between locational configuration and service utilization is established, the next step is to develop a network optimization model that systematically finds the location pattern and design characteristics that maximize the firm's performance. The approach to network optimization we present is based on an extension of the maximal covering model. Covering models are well suited for designing service networks because of their focus on accessibility. Though originally developed for siting emergency facilities such as ambulance and fire stations (e.g., Church and ReVelle 1974; Eaton, Church, and ReVelle 1977), they can be used to evaluate any network of outlets when the objective is to trade off the potential for utilization with the cost of providing the service (Craig and Ghosh 1984; Zeller, Achabal, and Brown 1980).

The basic objective of the maximal covering model is to find the spatial pattern that maximizes the number of potential users who are within a maximal travel time from service outlets. Potential users who are within the stated criteria are considered to be "covered." The assumption is that all potential users who are covered will actually use the service. A potential user whose nearest service outlet is beyond the stated travel time criterion is not expected to patronize the service outlets. The focus therefore is on defining a service level in terms of travel time and finding a location pattern that maximizes the proportion of total demand that is covered.

Though it is easy to implement, a major limitation of the maximal covering model is its reliance on a single accessibility criterion and the assumption that all potential users who are covered have an equal likelihood of using the service. To overcome this problem we extend the basic covering model by considering the level of coverage within a number of different travel time zones. The greater the accessibility to the outlet, we argue, the higher the probability of utilization. Further, whereas past applications of covering models have stressed geographic accessibility only, we explicitly consider the tradeoff between distance and nondistance factors. Thus, patronage is affected not only by travel time, but also by the level of different service attributes offered at the outlet. The effect of varying service attributes and travel times on service utilization is estimated through conjoint analysis Finally, we modify the traditional objective function to evaluate potential locational configurations in terms of expected profit rather than looking only at potential coverage. This approach allows a direct assessment of the cost and benefits of different network configurations.

To present our model we consider a planning region consisting of a set of discrete demand nodes I. The level of demand, that is, the number of potential users at any node i, is D_i. Let Q be the set of possible designs for service centers and A the set of accessibility classes considered. Individual members of the sets Q and A are designated as q and a, respectively. The accessibility classes are designated by defining upper and lower bounds for travel time. A simple scheme, for example, might be to consider travel times in intervals of 10 minutes and designate each 10-minute interval as a separate accessibility class. We then define S_{iqa} as the probability that a potential user at i will utilize an outlet that has design q and is in the a^{th} accessibility class from i. The firm's objective is to choose, from the set of feasible locations J, the sites that maximize the level of utilization. If the firm wishes to locate "p" outlets, the design and locational configuration of the outlets maximizing the level of total utilization can be found by solving the following combinatorial problem.

$$(1.1) \qquad \text{Max} \sum_{i\in I}\sum_{q\in Q}\sum_{a\in A} D_i S_{iqa} Y_{iqa}$$

subject to:

$$(1.2) \qquad \sum_{j\in N_{ia}} X_{jq} \geq Y_{iqa} \qquad \text{for all } i \in I,\ a \in A$$

$$(1.3) \qquad \sum_{a\in A} Y_{iqa} \leq 1 \qquad \text{for all } i \in I,\ q \in Q$$

$$(1.4) \qquad \sum_{q\in Q} X_{jq} \leq 1 \qquad \text{for all } j \in J$$

$$(1.5) \qquad \sum_{j\in J}\sum_{q\in Q} X_{jq} = p \qquad \text{for all } j \in J,\ q \in Q$$

$$X_{jq} = 0 \text{ or } 1 \qquad \text{for all } j \in J,\ q \in Q$$

$$Y_{iqa} = 0 \text{ or } 1 \qquad \text{for all } i \in I,\ q \in Q,\ a \in A$$

where:

$$N_{ia} = \{j \in J | d_{ij} \text{ is in accessibility class } a\}$$

As in all covering models, the objective of problem 1 is to maximize consumer accessibility to the network of centers. In this case, however, a weighting system is incorporated in the objective function to reflect the relation between accessibility and outlet design and the expected level of utilization. The variable X_{jq} is a zero-one decision variable that takes a value of one if there is an outlet at j with design q and zero otherwise. A critical component of the model is the N_{ia} variables, which are a set of vectors defined for each demand zone i. The vector $\mathbf{N}_{i1}$, for example, will include the index of all outlets that are in the first accessibility class from node i. These in turn determine the value of the coverage variable Y_{iqa} through constraint 1.2. For example, Y_{iq1} is zero if the set $\mathbf{N}_{i1}$ is empty, that is, if there are no outlets within the first accessibility class of node i. If there are one or more outlets in that accessibility class, that is N_{ia} is nonempty, Y_{iq1} attains a value of one. Note that in the objective function, this variable defines for each demand node i the particular likelihood value to be used in calculating expected utilization.

Constraint 1.3 ensures that when there is more than one outlet, only the outlet most likely to be used by the consumer is considered; thus double counting in the objective function is avoided. The constraint allows only one of the coverage variables for each node to be equal to one at the same time. As the objective is to maximize expected utilization, only the Y_{iqa} corresponding to the highest S_{iqa} is allowed to equal one. The implicit assumption is that potential users would visit only one outlet. Constraint 1.4 rules out the possibility that the same outlet is assigned more than one design and 1.5 limits the number of centers to "p."

Problem 1 presents the basic structure of our model. There are, however, several important considerations in applying the model. First, of course, is the estimation of the utilization function S_{iqa}. It can be based on subjective judgments of management or, preferably, developed through consumer surveys or structured choice tasks. A second issue is determining the optimal number of outlets to open. As currently formulated, the number of service centers p is exogenously specified. An important aspect of determining locational strategies, however, is to determine the optimal size of the network. To determine this size the model can be solved with different values of p and the tradeoff between utilization and investments plotted graphically. A more direct approach is to calculate the expected profit of each network and to choose the one that maximizes profitability (Achabal, Gorr, and Mahajan 1982; Ghosh and Craig 1983) This approach requires estimating the cost of establishing and operating service outlets and the revenues resulting from different levels of the service utilization. These extensions of the model and an example of its application are described in the next section.

MODEL APPLICATION

The situation chosen to illustrate the model's application involves designing a network of service centers for repair and maintenance of microcomputers. These "carry-in" service centers are to be operated by a major computer manufacturer.[1] Previously the company had offered only "on-site" repair service for mainframe and minicomputers. Because of the comparatively high cost of on-site service, the company believed carry-in centers would be a better way of offering repair service to owners of microcomputers. The primary target of these repair centers is small business owners of microcomputers. Large businesses, the company believed, are likely to continue their preference for on-site maintenance. The illustration is divided into two parts. First, we discuss the procedure for assessing the relationship between service attributes and travel times and the rate of utilization. We then describe an application of the network optimization model.

Assessing the Rate of Utilization

A preliminary step in assessing the rate of utilization is to identify the service attributes that affect consumer propensity to use the service centers. Personal interviews with present and potential users of microcomputers (among small business owners) and knowledgeable company officials helped in identifying four important attributes of repair centers: (1) travel time, (2) hours of operation, (3) speed of service (turnaround time), and (4) annual fee for a service contract. Each of these factors directly translates to implementable design attributes and is "actionable" by the company (Shocker and Srinivasan 1974).

The range of possible values for each of these attributes also was ascertained from interviews with potential users and company officials. Company officials maintained, for example, that the fee for annual service could not be less than $400. Potential users stated that a fee greater than $700 would severely limit utilization. Similarly, small business owners indicated that they would be unlikely to use the service if one-way travel time exceeded 40 minutes. On the basis of the interviews, four possible levels were identified for each service attribute.

—Travel time: <10 min., 10–20 min., 21–30 min., 31–40 min

—Hours of operation: 9–5 M–F, 9–8 M–F, 9–5 M–Sat., 9–8 M–Sat.

—Speed of service: <20 min., 2 hr., 24 hr., 48 hr.

—Fee for annual service contract: $700, $600, $500, $400.

Once the relevant service attributes and the possible levels of these attributes are identified, consumer sensitivity to these attributes can be ascertained through conjoint or logit techniques. These methods have been used widely in marketing to estimate the effect of product characteristics on brand preference and choice.[2] However, relatively few applications to retail settings have been reported (Burnett 1982; Louviere and Woodworth 1983; Parker and Srinivasan 1976; Recker and Schuler 1981). To measure the impact of the service attributes and accessibility on the utilization of service centers, a conjoint task was designed. In general, we assume that if there are S service attributes, an attribute s can take M_s possible values, and there are A accessibility classes, the likelihood that an individual will utilize a center at j is

$$S_{ijsma} = \sum_{s=1}^{S} \sum_{m=1}^{M_s} \beta_{sm} Z_{jsm} + \sum_{a\in A} \gamma_a V_{ia} \qquad (2)$$

where Z_{jsm} is one if the outlet at j has the m^{th} level of attribute s and V_{ia} is one if the travel time between i and j is in the a^{th} accessibility class. Both variables take the value of zero otherwise. The β parameters measure the marginal change in utilization resulting from a change in the design and γ defines the impact of changes in travel time. Note that because there are a finite number of discrete levels for each attribute, the set of all possible designs can be generated by permutation. This is the set Q in problem 1. Equation 2 therefore can be written as

$$S_{iqa} = \sum_{q\in Q} \beta_q Z_{jq} + \sum_{a\in A} \gamma_a V_{ia}. \qquad (3)$$

To estimate equation 3 empirically, a set of hypothetical service configurations was created according to a full-profile factorial design. Respondents were asked to evaluate the likelihood of using the service on a scale from zero to 100. Evaluations of the profiles were obtained from 458 small business owners in the planning area through a mail survey. The responses to the profiles can be analyzed at different levels of aggregation (Currim 1981) ranging from analyzing responses from each respondent separately (Parker and Srinivasan 1976) to aggregating all responses to parameterize once for the entire sample (Burnett 1982; Eagle 1984; Louviere and Woodworth 1983). An intermediate approach is to segment the respondents on the basis of situational factors (Belk 1975; Wind 1978) and to calibrate the utilization function separately for each segment (Currim 1981). Because investigations during the pretest phase of the study had indicated that utilization rates may vary according to the population density of the area, a segmentation approach is used here. The responses first were divided into two segments based on the area's population density where the business was located and separate utilization functions were calibrated for each segment.[3] The reli-

[1] The firm, one of the large computer manufacturers, wishes to remain anonymous

[2] For a detailed discussion on the use of conjoint procedures in marketing, see Green and Srinivasan (1978)

[3] Several other segmentation criteria were applied. However, none resulted in significant differences among groups

ability of these utilization functions was checked by split-half procedure. Respondents in each segment were split randomly into two groups and partworths were computed for each group. For both segments the estimated parameters for the two groups were not significantly different from each other.

Of the four attributes, consumers were most sensitive to operating hours, followed by travel time and cost of service. The speed of service had relatively little impact on utilization. For both segments, increasing the operating hours increased the likelihood of utilization. In addition, for respondents from the low density area, Saturday operations increased the probability of use. Another major difference between the two segments was the sensitivity to travel time. As might be expected, respondents from the more densely populated areas were more sensitive to travel time than their counterparts from less densely populated areas. Also, respondents from the low density segment, in general, indicated a higher likelihood of using the service. The probability that a small business owner in the low population density segment would use a service center that is open 9–5 M–F, requires travel time of less than 10 minutes, has a turnaround time of 20 minutes, and charges $400 for a one-year service contract is .616. The probability that a small business owner in the high population density segment would use a similarly configured service center is .503.

Estimating Potential Demand

To implement the optimization procedure, a geo-coded data base was created by using the spatial coordinates of the 164 towns and cities in the planning region. Each location was assigned to one of two segments depending on the level of population. On the basis of land availability and infrastructural development, 124 of the towns were designated as feasible sites for opening service centers. The travel time from each demand node to these potential sites was determined with the help of detailed road maps and assessment of traffic speeds on different categories of roads.

To estimate demand, information on the number of small businesses and employment in small businesses was gathered from census publications and other secondary sources. Information on the present and expected level of computer ownership was gathered through a mail questionnaire. In addition, the firm's share of microcomputer sales in the area was estimated by company officials. Because the service is new, only a fraction of the total potential can be realized in the initial phases of the project. With time, however, this fraction is expected to increase. Though several different growth functions were used, the results reported here are based on an exponential function. The potential demand at time t, D_{it}, is calculated as $D_i(1 - e^{-\lambda t})$.

Calculating Profitability of Networks

To evaluate the profitability of different networks, the profit consequences of different strategies must be calculated. The revenue and cost associated with different networks depend, in addition to the location pattern, on the design of the service outlets. The annual fee for a service contract affects the utilization rate—the lower the fee, the greater the utilization. Lower fees, of course, reduce the profit per contract. Similarly, though quicker turnaround time and longer operating hours increase utilization, they raise the cost of providing service. The best design therefore must be chosen carefully by evaluating the tradeoff between cost and revenue associated with different strategies.

In general, three types of cost must be considered. One type is annual operating cost representing cost of manpower as well as the cost of equipment and working capital. The second is annual rent or site cost. Both of these types of cost are affected by service design. In general, the higher the level of service, the greater the cost of providing it. We refer to the sum of these costs as the fixed cost of operating an outlet.[4] The third type of cost is the variable cost of servicing each customer. It depends on the expected failure rates and the cost of replacement parts. Such information can be obtained from engineering estimates of product reliability and mean times to failures.

The profitability of a network over a planning horizon of T years now can be written as

$$(4) \quad \sum_{t\in T}\left[\sum_{j\in J}\left[\left(\sum_{i\in I}\sum_{q\in Q}\sum_{a\in A} D_{it}S_{iqa}Y_{iqa}U_q\right) - F_{jqt}\right]\right] \Big/ (1 + r)^t$$

where U_q is the contribution earned from a service contract in an outlet with service design q, F_{jqt} is the fixed cost of an outlet with design q at site j, and r is the discount rate used by the firm. This equation is used in the objective function of the covering model, replacing the more general formulation presented before. Note that for clarity of presentation the subscript for segments is not shown in equation 4.

In applying the covering model a number of parameters must be estimated. In addition to information on travel times and demand, values must be specified for U_q, F_{jqt}, λ, r, and T. For the purpose of our illustration we assume a planning horizon of 10 years and a discount rate (r) of 20%. The annual site cost for an outlet is estimated to be $250,000. The cost of operation varies with the design and is based on estimated manpower requirements. The annual cost of operating an outlet that is open 9–5 M–F and provides 24-hour turnaround time, for example, is $117,000. Longer operating hours and faster turnaround time increase manpower requirements and hence operating costs. Finally, an exponent of 5 was used to estimate the growth of potential with time

[4]For clarity of presentation, we assume that these costs are spatially invariant. Site costs tend to show spatial variation, but the size of the center and its layout often are adjusted to keep rents relatively constant across outlets.

Because of the excessive computer time required to solve large combinatorial problems with exact algorithms, a vertex substitution algorithm fashioned after that of Teitz and Bart (1968) was used to solve the covering problem. Note, however, that in contrast to other locational algorithms, this one searches in both geographic and attribute space to determine good locational and design characteristics simultaneously. Though heuristic algorithms do not guarantee global optimality, past experience has shown locational algorithms based on vertex substitution to be successful in finding a near-optimal if not *the* optimal solution (Achabal, Gorr, and Mahajan 1982). To reduce the possibility of local optima, each problem was solved with three different starting configurations.

Results

The results of applying the model in the planning area are reported in Table 1. The table shows the percentage of small businesses covered by networks with different numbers of service outlets. To be covered, a small business must be less than 40 minutes away from at least one service center. As might be expected, coverage increases as more outlets are added. However, the marginal coverage provided by new outlets diminishes rapidly. Beyond six outlets, each additional outlet adds less than 2% to total coverage.[5]

An essential element of location strategy is the decision on the number of outlets to open in a market area. In many locational models this decision is made exogenously. In the approach we use, however, the optimal number of outlets can be determined directly from the results of the analyses. The decision on network size must be based on comparing the cost of establishing and operating an additional outlet with the expected gain in revenue from increased coverage. Table 1 shows the profit consequences of different levels of coverage achieved by alternative network configurations. When only one center is opened the expected net present value (NPV) is $2,657,500. The addition of a second outlet increases the NPV of the network by $1,701,100 to a total of $4,358,600. As more outlets are opened, however, the marginal profit decreases because the marginal coverage provided by new outlets becomes progressively smaller. The NPV of a five-center network, for example, is $5,537,100, which is only $26,900 more than the expected NPV of the four-center network. The NPV decreases when more than five centers are opened. The marginal NPV of a six-center network is a loss of $245,700. Thus, though the expected NPV of a six-center network is substantial, the return on the incremental investment for the sixth center itself is not adequate. On the criterion of return on the marginal investment, only five centers should be opened in the region.

[5]Though not shown in Table 1, 16 centers are required to provide 100% coverage

Table 1
COVERAGE AND PROFITABILITY OF DIFFERENT NETWORKS

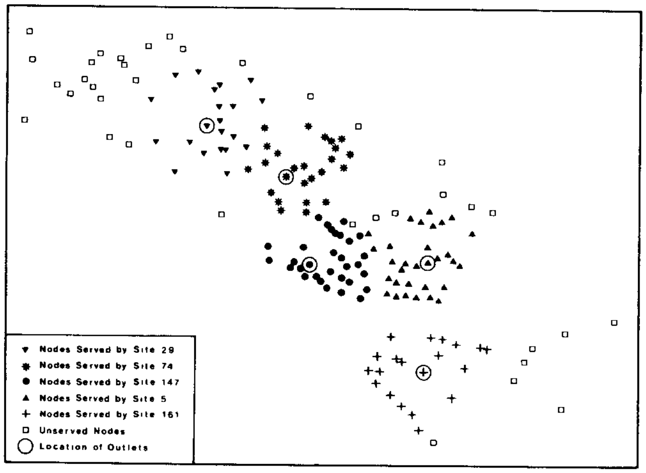
Number of centers	*Percentage of small businesses covered*	*Marginal coverage*	*Net present value ($ 000s)*	*Marginal net present value ($ 000s)*
1	29.7	29.7	2657 5	2657 5
2	49 6	19 9	4358.6	1701 1
3	65.1	15 5	5228.6	869.9
4	75 4	10 3	5510.2	281 6
5	84 7	9.3	5537.1	26 9
6	91.5	6 8	5291 4	−245 7
7	93 4	1.9	4312 2	−979.2
8	95 1	1 7	3322 1	−990 1
9	96 6	1 5	2295.0	−1027 1
10	97 8	1 2	1242 0	−1053 0
11	98 7	0 9	183.2	−1058.8
12	99 5	0 8	−1073 1	−1256 3

The expected profit and therefore the decision on the optimal network size depend on the values of the parameters in the model. A longer time horizon or a lower discount rate, for example, would increase the level of expected profit. Reducing the discount rate to 12% increases the marginal NPV of the sixth center and makes a six-center network attractive to operate. Increasing the planning horizon to 15 years also changes the optimal size of the network to six outlets. These parameters therefore should be chosen with care and should be consistent with the figures used in other capital budgeting decisions of the firm (Achabal, Gorr, and Mahajan 1982). Outlet profitability also depends on cost of operations. A reduction in the cost of operating the outlets allows the establishment of larger networks.

The profit associated with different networks is contingent on following the best locational plan and service design strategy chosen by the algorithm. The best sites for the five-center network are shown in Figure 1. The expected profit of $5,537,100 can be realized only if these sites are chosen. A change in the locational plan would also change the profitability of the network. Decisions about the number of outlets and their locations are interrelated and cannot be made separately. Table 2 shows the performance of each outlet in the five-center network in terms of coverage, expected number of annual service contracts, and profit. The outlet at site 161, for example, is expected to serve only 780 contracts whereas the one at site 74 is expected to serve nearly twice as many. Such information is important in planning workload distribution and manpower, equipment, and working capital requirements. The outlet at site 74 provides the maximum coverage and accounts for 31.2% of the total profit accruing to the system. The outlet at site 161, in contrast, accounts for only 4.4% of the total profit. Outlets at the other sites contribute approximately 20 to 25% of the profit.

It is interesting to compare the performance of indi-

Figure 1
THE FIVE-CENTER NETWORK: LOCATIONS AND SERVICE AREAS



vidual outlets in the five-center network with that of the ones in the six-center network (Table 2). The two networks have four sites in common (sites 5, 74, 147, and 161). The center at site 29 in the five-center network is replaced by outlets at sites 30 and 48 in the sıx-center one. The combined profit of the two new centers is $4200 more than that of the outlet at site 29 (Table 2). The total profit of the six-center network, however, is $245,700 less than that of the fıve-center network. In addition to increasing fixed cost, the new outlets at sites 30 and 48 draw many of theır customers from the service area of the center at site 147. The expected number of annual contracts at site 147 decreases by more than 10% with the establishment of these two centers. Consequently, the NPV of this outlet reduces from $1,387,000 ın the five-center network to about $1,137,100 in the six-center one—a reduction of about 18% Thus, as more outlets are added to the network, much of the profitability of the new outlets results from the cannibalizatıon of sales from existıng ones. Though the new outlets are profitable when viewed ındependently, they reduce the earnings of the existıng ones and the profitability of the total system. It ıs important, therefore, to evaluate the effect of an outlet by considering the entire network of centers rather than individual outlets separately.

Table 2
COVERAGE, WORKLOAD, AND PROFITABILITY OF INDIVIDUAL CENTERS

Center locatıon	Number of small busınesses covered	Expected number of servıce contracts	Expected net present value ($ 000s)	Percentage of total profıt
Fıve-center network				
5	13,711	1221	1106 1	20 0
29	13,424	1206	1076 4	19 4
74	18,681	1537	1726 2	31 2
147	16,907	1364	1387.0	25 0
161	9,106	780	241 4	4 4
Sıx-center network				
5	13,711	1221	1106 1	20 9
30	12,123	1085	840 0	15 9
48	8,709	779	240.6	4 5
74	18,681	1537	1726 2	32.6
147	15,312	1237	1137 1	21 5
161	9,106	780	241 4	4.6

Figure 1 shows the locations of the 164 towns ın the planning regıon, the sites of the fıve centers, and the service area of each outlet. Knowledge of the towns covered withın the trade area of each outlet is ımportant to managers of the service system for developing promotion and sales strategies. The square symbols in the figure represent demand areas that are not covered by any of the five outlets. They are mainly in the southeast and northwest corners of the planning area where demand is low. In addition, a few unserved demand points lıe in the interstices of the trade areas of the outlets. These uncovered points represent lost potential, but the cost of providıng servıce to these places far outweighs the expected revenue.

As noted before, the algonthm provides not only good locations, but also the best desıgn. For the five-center network, the optimal design is a turnaround time of 24 hours, operation 9–5 Monday to Saturday, and an annual fee of $700. The effect of changes in design on profitability is shown in Table 3. From the user's perspective the system is most attractive when the annual fee is $400, turnaround time is 20 minutes, and the centers are open 9–8 Monday through Saturday. This design would increase utılization and the expected number of contracts to 6864—a 12% increase over the optimal design. The profitabilıty of the network would declıne, however Patronage increases with lower fees, but the ıncrease is not enough to compensate for the lower contribution per contract. In addition, faster service and longer operating hours increase the cost of operating the system. Thus, though thıs is an attractive design, the lower revenue and hıgher cost make it less profitable than the best desıgn chosen by the algorithm. Sımilarly, though the operatıng cost could be decreased by longer turnaround time and shorter operating hours, utilization and profıtability would be adversely affected. The design chosen by the model reflects the best tradeoff between cost and revenue and maximizes systemwide profitabılıty.

Model Extensions

The basic approach presented here can be extended ın a number of ways. For example, our illustration ınvolves locatıng all new outlets, but the model also can be used to relocate existing servıce centers or to add new outlets to an existıng network. In the former case, relocation strategıes can be found by comparing the optımal solu-

Table 3
IMPACT OF CHANGE IN DESIGN ON PROFITABILITY FOR FIVE-CENTER NETWORK

Annual fee ($)	*Turnaround time*	*Operating hours*	*Expected number of contracts*	*Annual fixed cost ($ 000s)*	*Net present value ($ 000s)*
700	48 hr	9–5 M–F	4524	825	3529
700	48 hr.	9–8 M–F	5404	950	5252
700	24 hr	9–5 M–F	4960	922	3971
700	24 hr.	9–5 M–S	6107	1088	5537
700	24 hr	9–8 M–S	6437	1280	5367
600	24 hr	9–5 M–S	6405	1085	4088
500	24 hr	9–5 M–S	6499	1085	2182
400	48 hr.	9–5 M–F	4917	825	−382
400	<20 min.	9–8 M–S	6864	1700	−2089

tion with the existing configuration. To determine an expansion strategy, existing outlets can be forced into the solution by constraining the decision variables (X_{jq}) corresponding to the existing outlets to one. A similar procedure can be followed to locate some outlets at "prestige" sites. The model then determines the location of the remaining outlets given these fixed sites.

The location of competitive outlets also can be considered in the proposed framework. However, a rule must be specified to determine the allocation of potential when consumers are covered by outlets belonging to more than one firm. A simple rule might be to allocate consumers to the outlet they are most likely to use. Alternatively, a probabilistic allocation rule based on the service offerings and accessibility of different outlets can be used. In either case, information on service offerings and locations of competitive outlets must be obtained.

CONCLUSION

We present a method for jointly developing a locational strategy and service design characteristics for a network of new service outlets. The procedure is comprehensive in that it encompasses, within a single decision-making framework, questions about network size, locations of centers, pricing, and operating characteristics. In making these decisions, the procedure takes into consideration the spatial variation in potential demand and the variation in expected utilization among different segments of potential customers. Because these are important components of marketing strategy for retail services, the procedure we present should prove useful to retail firms. The basic procedure can be modified to incorporate different and more service design elements as well as to consider more than two segments and use parameters other than those in our illustration.

We also demonstrate a method for assessing consumer sensitivity to service characteristics and travel time and the manner in which consumers trade off distance for nondistance factors. This procedure allows an estimation of expected demand as a function of accessibility and design characteristics. Thus, the method is well suited for new services in that it does not rely on analysis of past choice behavior. The reliance of many retail location models on revealed preference data severely limits their usefulness when a new distribution system is being established.

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