"OPTIMAL TIMING AND LOCATION IN COMPETITIVE MARKETS"

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ABSTRACT

The choice of a good location strategy is one of the most crucial decisions facing a retailer. While a number of recent articles have addressed the issue of site selection, the related issue of optimal timing and preemption has been largely ignored. In this paper, we present an integrated location-allocation model that allows a retailer to formulate an overall location strategy by addressing the questions of *how many* stores to open, *where* to open them, and *when* to open them. In addition, the model explicitly incorporates demand growth scenarios and takes into account the dynamics of competitive actions. As an illustration of its use, the model is applied to a simple yet realistic decision scenario.

OPTIMAL TIMING AND LOCATION IN COMPETITIVE MARKETS

In the early 1960s several researchers, working independently, proposed location allocation procedures for solving spatially structured combinatorial problems (see, for example, Kuhn and Kuenne 1962, Cooper 1963; Kuehn and Hamburger 1963, Maranzana 1964). They proposed systematic procedures for determining the optimal or near-optimal locations for providing goods and services to a spatially dispersed set of users. Location allocation procedures involve the selection of facility locations and the assignment of demand to those locations in order to optimize some desired objective. Since the optimal locations depend on the allocation pattern, and the allocations depend on the location, both features must be determined simultaneously. During the past two decades location allocation models have been applied in a variety of situations to determine optimal or desirable locations for providing goods and services (for reviews of this literature see, ReVelle, Marks and Liebman, 1970; Hodgart, 1978; Leonardi, 1981; Hansen, Peeters and Thisse 1983, and Ghosh and Rushton 1987). Examples of use of location allocation models in retail settings --the context of this paper-- are given by Achabal, Gorr and Mahajan (1982), Ghosh and McLafferty (1982), Goodchild (1984), Ghosh and Craig (1984), Ghosh and Craig (1986), and Goodchild and Noronha (1987). In this paper we present a location allocation based procedure for determining the optimal location and time for opening new retail facilities in a competitive environment.

To describe a typical location allocation problem, consider a study area which comprises a number of geographical locations from which the demand for services originates. The level of demand at each location is known along with a set of feasible sites for locating new facilities and the shortest distance between each demand location and each feasible site. Also known are the locations of existing facilities, if any, that provide similar goods and services. Next a rule for allocating demand at each location to each feasible site is specified. The allocation rule should be based on expected patterns of consumer behavior (when consumers travel to the service) or on the logistical characteristics of the service (when the service is delivered). Now if the objective criteria for evaluating the service delivery system is specified, the location or locations that optimize these stated criteria can be found. This, according to Ghosh and Rushton (1987) is the *classic* location allocation problem.

The classic problem deals with simple, well-defined environments where the spatial pattern of demand is stationary and in which deterministic spatial allocations can be made. In recent years, researchers have focussed their attention on location allocation models that deal with complex environments and probabilistic allocation rules (see, for example, Hodgson 1978; O'Kelly 1987). There has also been considerable interest in applying location allocation procedures to environments where two or more firms operating multiple outlets compete in attracting customers to their facilities. As Hakimi (1981) noted, many location allocation models deal exclusively with noncompetitive situations, in which the effect of competitive facilities on locational performance is ignored. While ignoring the competitive environment may not be a drawback when dealing with public facility locations, the application of location allocation models to private sector problems requires explicit consideration of the competitive environment. In a competitive environment a location deemed attractive initially, may become unattractive as competitors locate additional facilities to achieve their own goals. Thus the objective must be to select sites that not only maximize performance in the short run but also protect that performance from future competitive actions. A number of researchers have now proposed models that deal with facility locations in competitive situations (see, for example, Presscott and Visscher 1977; Hakimi 1981; Ghosh and Craig 1984).

Although these competitive models have made possible significant advances in location allocation modeling, the *timing of entry* decision has been rather neglected in them. Existing models assume that decisions are made at the start of the planning horizon and that all facilities are located at this point in time. However, like location, the timing of new store openings, too, should be determined with care depending on the changes in demand patterns, availability of sites, and expected competitive locations. Thus, the firm's problem is not only to determine the location of facilities but also to determine when these facilities should be established --that is, to select the optimal time-table of facility openings and their locations. The objective of this study is to present a systematic procedure for selecting the optimal location and time for establishing facilities in a competitive environment.

Selecting the optimal time table for facility openings is somewhat similar to the problem of determining the optimal times for capacity expansions in response to changing demand levels (Haynes et al. 1984), the optimal time for switching from export to direct investment in foreign markets (see, for example, Rao and

Rutenburg 1977; Buckley and Casson 1981), the timing of R & D investments (Scherer 1967), and the timing of technology adoption (Reinganum 1981; Kim, Röhler and Tombak 1990). While these problems are related in that they all address the issue of serving demand growth, they are devoid of any locational decision. For example, the locational component is completely lacking in the R & D investment scenario. In the capacity expansion problem the locational component is often assumed to be fixed, and only the capacity of existing facilities is considered. The separation of the timing and the locational components simplifies the problem considerably. However, in many situations one has to deal with not just established locations but either build a network from scratch or expand on an existing set of outlets. The optimal time-table in these situations will be affected by the availability of feasible locations over time, temporal changes in demand, and the dynamics of competition among firms in the market.

The rivalry among competing firms has a significant impact on the optimal time for a firm to enter a market. In a noncompetitive environment the timing decision may be seen as a trade off between the cost of establishing the facility and the discounted future returns from providing the service. The decision is much more complex, however, if the competitor is expected to open new outlets too. There are a number of reasons for this additional complexity. First, the competitor's outlet will affect the desirability of a chosen location, since store revenues depend on the relative location of all outlets in the market. The second source of complexity is competitive preemption. The competitor may enter the market early and locate at a site that the firm desired for itself. Such competitive preemption reduces the locational options available to the firm and, therefore, will have a negative impact on the firm's long term profit. Finally, early entry by competitors may establish a degree of consumer loyalty towards that firm so that the later entrant may not realize the full potential of its facilities.

Thus in making facility timing decisions in competitive markets, firms must try to anticipate when competitors are likely to establish their own facilities and the specific sites at which these outlets are likely to be opened. To anticipate competitive moves the firm must see things from the competitors' eyes and assume that the competitor will act rationally and with the same degree of sophistication as it does. As Presscott and Visscher note, to reason otherwise would imply that the "firm mistakenly considers itself a profit maximizer in a world of fools" (1977, p. 391). It is often suggested that when faced with uncertainty about competitors' likely actions, a rational firm should use a game theoretic perspective and choose the strategy that maximizes the minimum payoff it is likely to receive (Von Neumann and Morgenstern 1944; Rapoport 1973; Harsanyi 1982). The game theoretic perspective has been applied to a number of locational problems with considerable success (Stevens 1961; Isard and Smith 1967; Teitz 1968; Hakimi 1981; Ghosh and Craig 1984) and provides a particularly appealing framework for making locational decisions in competitive markets.

Ghosh and Craig (1984) presented a location allocation model based on the rationality postulates of game theory to deal explicitly with site selection in a competitive environment. Their model evaluates the desirability of multiple locations in terms of both existing as well as possible future competitive locations. Thus, one approach to solving the optimal timing problem could be to extend Ghosh and Craig's framework by incorporating the timing dimension into their locational model. The drawback with such an extension, however, is that it requires the first entrant into the market to be specified exogenously --only then can the competitive reactions be specified. But in reality a firm cannot decide whether to be a leader or a follower in a market without considering the potential payoffs from these strategies. Therefore, a model for developing the locational time table must consider market leadership as endogenous to the model. That is, the identity of the first entrant must be a result of the model and not an input to it. This, and the explicit consideration of time of entry is our point of departure from earlier competitive models.

The rest of the paper is divided into two major sections. The next section develops an approach to facility planning in dynamic environments that deals explicitly with both location and timing issues. The model determines whether a firm should be the first entrant or a follower in a market. If it is optimal for the firm to preempt the market, the model develops an optimal time table for facility openings and identifies the sites at which those facilities should be located taking into consideration existing as well as the future competitive environments.[1] In situations where it is not optimal for the firm to preempt, the model specifies the best way in which the firm can react to its competitor's preemptive move. It uses a game theoretic perspective to deal with the uncertainty of competitive actions in determining the optimal locational plan. In addition, the model

[1] We use the term preemption to refer to the first move that changes the status quo in a market.

can be used to determine the optimal number of facilities that the firm should open and whether these facilities should be opened one at a time or all together. The aim is to provide an overall framework for designing a locational strategy by addressing the issues of ***how many* facilities** to open; *when* to open them; and *where* to locate them. The second section of the paper illustrates the application of the model to a simple yet realistic decision scenario. The results of this application and some further extensions to the model are discussed in this section.

The Optimal Location Timing Model

As noted earlier, determining the optimal timing and location of facilities in a competitive environment is complicated because of the number of factors that have to be considered simultaneously. In this section we present a decision making procedure for determining the optimal time and location for facility openings. To facilitate presentation consider two retail chains competing in a defined market area. The outlets of these chains provide similar product offerings at comparable prices. One of the chains (Chain A) is planning to open a new facility in the area in order to increase its market presence. Managers of the chain have reason to believe, however, that its competitor (Chain B) also plans to open a new outlet in the area. What locational strategy should Chain A follow: When should it open its new outlet and where should the outlet be located?

Our proposed approach to solving the problem is to specify a set of decision rules that the firm can use at any point in time to determine its optimal strategy. These decision rules are dynamic in that the outcome changes over time depending on the actions of the firm and the competitor in previous time periods, likely competitive reactions in the future, and expected changes in the demand environment. It is through the application of these decision rules that the identity of the first entrant and the optimal location and timing choices of all firms are determined. Inherent in our approach is a view of how competitive rivalry evolves and how firms make decisions. We view the latter as a sequential process in which at each time interval the firm asks itself what it should do. This is in contrast to the firm committing itself to entry times and locations at the start of the planning horizon. As mentioned, for such a strategy to be viable the firm must commit itself to preempting the market a priori. Thus our equilibrium concept is consistent with the notion of *noisy* equilibrium discussed by Hendricks and Wilson (1989), in which firms cannot commit to a strategy at the beginning of the game but decide at each time period taking into consideration past and future realizations of the game.

Consider the time horizon to comprise t discrete time periods $t=1, 2, \ldots, T$. Following Cyert and DeGroot (1970) we assume, for convenience, that firm A makes decisions during odd time periods $\{t=1, 3, \ldots, T-1\}$ and firm B during even ones $\{t=2, 4, \ldots, T\}$. At any odd decision period Chain A can be faced with one of three possible scenarios:

I. *Both firms have already located their full complement of stores.*

If this is the case, there is no new decision to be made.

II. *Firm B has already entered the market.*

In this scenario Chain A does not have the opportunity to preempt anymore. It has to decide on the best way to react to B's strategy by selecting its own time of entry and optimal site for the new facility. To select its optimal reactive strategy, Firm A must identify the location-time combination that maximizes discounted future profits, given Chain B's decision. In other words, Chain A's strategy will depend on the location of its competitor's new outlet and the time at which that new outlet was opened.

III. *No firm has opened new outlets yet.*

In this scenario Chain A has to decide whether it should locate a new outlet at this time or whether it should enter the market at a later period. If it decides to preempt, it also has to decide on its optimal location. The firm should choose between entry or waiting based on the expected payoffs from following these strategies. The payoff from market entry depends on the competitor's reaction. If A enters the market at time t, the competitor can respond at $t+1, t+3, t+5, \ldots, T$ and locate its outlet at any one of the still available feasible sites. Chain A must anticipate which one of these many strategies the competitor is likely to choose. Note that this is similar to the problem in Scenario II with the roles of the two firms reversed.

Firm A, of course, has the option of not entering the market at time t. To calculate the value of waiting, Chain A has to determine B's likely strategy in the future. Chain B may decide to locate at any of the future time periods, or not locate at all. But, in making its decision Chain B will have to anticipate A's response to whatever strategy it adopts. Thus, A's decision not to locate at time t is contingent on its expectation of how B would act in the future and how it would react to B's strategy. Because of the mutually contingent nature of the decision, it can give rise to considerable computational burdens when a large number of time periods have to be considered.

The computational burden can be reduced significantly, however, by noting a result which follows from Rao and Rutenburg (1977). Suppose at time $t=5$ no firm has yet entered the market and Chain A has to decide whether to enter the market or not. Further assume that Chain A decides not to enter the market at this point of time. Define this decision scenario as $A_5[A(W)B_k]$; i.e., at $t=5$ A waits and k is the optimal time for B to enter. Suppose Firm B's best reactive strategy is to enter during the tenth time period; i.e., $k=10$. This implies that the optimal value of k in the decision scenarios $A_7[A(W)B_k]$ and $A_9[A(W)B_k]$ is also 10. On the other hand, if the optimal value of k in $A_5[A(W)B_k]$ is 6 then A will never face the decision scenario $A_t[A(W)B_k]$ for any $t > 6$. In other words, if B's optimal strategy is to enter the market at time 6, A will no longer have the option of preempting the market at $t=7$, it can only react to Firm B's entry. Thus, at $t=5$ Chain A must decide between waiting or entry based on its expectation of what Chain B will do in period 6. The implication is that to calculate the value of waiting at any time a firm need only consider the competitor's likely reaction in the very next decision period. This makes the optimal timing problem numerically tractable since it implies that one deals only with pairs of time periods. The entire sequence of optimal strategies can be found by defining each pair of consecutive time periods as the decision space and determining the Nash strategies for each consecutive pair of time periods.

Evaluating Options At Each Time Period

In this section we develop the structure of the game at each time period. We develop the game for an odd time period when Firm A can make a decision, but note that in solving the game similar expressions are developed for even time periods also (that is, for Chain B's decision). An inspection of the three scenarios described earlier reveals that a firm is in a proactive decision making mode only in Scenario III. No decision is necessary in Scenario I, and in Scenario II a firm can only react to its competitor's preemptive move. In Scenario III no firm has yet entered the market and Chain A is faced with the decision whether to preempt the market or to wait for a future time period to enter the market. If Chain A preempts the market at time t, the payoff from market entry will depend on the time at which B reacts and B's locational choice. To determine its pay off from waiting the firm has to consider whether Chain B would also wait or preempt the market at time t+1. Thus, the structure of the game at time period t can be visualized as follows:

A's decision at t	B's decision at t+1	A's payoff	B's payoff
Wait	Wait	rA_1	rB_1
Wait	Build	rA_2	rB_2
Build	Respond at t_k	rA_3	rB_3

where rA_1, rA_2 and rA_3 are Firm A's payoff, and rB_1, rB_2, and rB_3 Chain B's payoff respectively.

If Chain A decides to wait, B will build at time t+1 if $rB_2 > rB_1$. On the other hand if $rB_1 > rB_2$ Chain B will also wait during t+1. Therefore, Chain A's payoff from waiting is rA_1 if $rB_1 > rB_2$ and rA_2 if $rB_2 > rB_1$. To determine its optimal strategy Chain A must compare its payoff from waiting against rA_3 and choose the strategy with the higher payoff. Therefore, we can write Firm A's decision rule as follows:

IF $rB_2 > rB_1$ THEN

A should ENTER at time t if $rA_3 > rA_2$

A should WAIT at time t if $rA_2 > rA_3$

IF $rB_1 > rB_2$ THEN

A should ENTER at time t if $rA_3 > rA_1$

A should WAIT at time t if $rA_1 > rA_3$

These rules specify how A should make its decision at each time period. A parallel set of rules can be established for firm B. To determine the equilibrium solution to the timing location game we apply these rules to both firms and determine the earliest time period at which any Firm A (or Firm B) will decide to enter the market. Let $A_{t\cdot}$ be the earliest time period during which A will decide to preempt and let $B_{t/}$ be B's best response to A's move. Similarly let $B_{t\cdot}$ be the earliest time period when B can preempt and let A's optimal response be to enter the market at $A_{t/}$. Then if $A_{t\cdot}$ is earlier (later) than $B_{t\cdot}$, Firm A (B) will preempt the market at time $A_{t\cdot}$ ($B_{t\cdot}$) and Firm B (A) will respond at time $B_{t/}$ ($A_{t/}$).

Calculating Payoffs

This section describes the procedures for calculating the payoffs for each strategy and determining the optimal location if the firm decides to enter the market. If neither firm locates any new stores, the future profits of the two chains will depend on the locations of the existing stores, the pattern of demand at future time periods and the rule for allocating demand to facilities. Let $RA_t(0)$ be A's profits during time period t, when no new outlets are open in the market. Similarly let $RB_t(0)$ be B's profits during time period t under existing conditions. When one chain adds a new outlet, it enhances its competitive advantage and attracts more customers to its network. The competing chain may lose some customers as a result. Define $RA_t(1)$ and $RB_t(-1)$ to be A's and B's profits respectively at t when chain A has preempted the market. Similarly, let $RB_t(1)$ and $RA_t(-1)$ be the profits for B and A respectively when B preempts. Finally, let $RA_t(2)$ and $RB_t(2)$ be the profits for A and B respectively when both chains have located new stores in the market. We use these definitions to specify decision rules for each firm.

ΓA_1 & ΓB_1: Consider the case when neither firm has entered the market. At time t Firm A's expected payoff is the discounted present value of its future profits (t, t+1, ..., T) under current conditions. That is:

$$\Gamma A_1 = \sum_{k=t}^{T} \frac{RA_k(0)}{(1+r)^{(k-t+1)}} \tag{1}$$

Similarly:

$$\Gamma B_1 = \sum_{k=t}^{T} \frac{RB_k(0)}{(1+r)^{(k-t+1)}} \tag{2}$$

ΓA_2 & ΓB_2: How would A's payoff change if Chain B decides to enter the market at time t+1? In this case Chain A's payoff will depend on how it responds to B's preemption. Suppose A responds to B's preemption by entering the market at time t_A ($t_A > t+1$). Then A's payoff is[2]:

$$\Gamma A_2 = RA_t(0) + \sum_{k=t+1}^{t_A-1} \frac{RA_k(-1)}{(1+r)^{k-t+1}} + \sum_{k=t_A}^{T} \frac{RA_k(2)}{(1+r)^{k-t+1}} \tag{3}$$

The first expression in Equation 3 is A's profit at time t. The second expression is the discounted value of A's profits from t+1 to (t_A - 1), the period during which Chain B has an advantage in the market. The final term is the value of A's profit during the period when both firms have new outlets in the market. To determine its optimal response to Chain B's decision is to enter the market at time t+1 Chain A must determine the t_A ($t+1 < t_A < T$) that optimizes the following objective function:

$$\underset{t_A > t+1}{MAXIMIZE}\ [\Gamma A_2] \tag{4}$$

Given Chain A's optimal response is to enter the market at t_A, the present value of chain B's strategy of entering the market at time t+1 is as follows:

$$\Gamma B_2 = \sum_{k=t+1}^{t_A-1} \frac{RB_k(+1)}{(1+r)^{k-t+1}} + \sum_{k=t_A}^{T} \frac{RB_k(2)}{(1+r)^{k-t+1}} \tag{5}$$

Since a firm's payoff depends on the particular site at which it locates its new store, the issue of determining the optimal time cannot be separated from the optimal location decision. In determining its optimal strategy Chain A in addition to determining the optimal time of entry must also determine the site that maximizes its payoff. To relate an outlet's profits to the spatial distribution of demand, we write,

$$Q_{it} = \sum_{j=1}^{N} (D_{jt} A_{ij} C - F_{it}) \tag{6}$$

where Q_{it} is the profit at location i (i=1, 2, ..., M) during period t, D_{jt} is the demand originating from zone j (j=1, 2, ..., N) at time t, A_{ij} is the proportion of the expenditure from j that is allocated to the outlet at i, C is

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[2] We assume that a facility opened at time t starts operating at the beginning of that time period and all profits accrue at the end of the period.

the gross profit margin as a percent of store revenue, and F_{it} is the fixed cost of operating the store at i during period t. To determine the best location Chain A must find the profit maximizing site i, given the location of the existing stores.

Let the sites be indexed such that i=1,2, ..., i' are the location of all of Chain B's existing and new outlets, $i=i'+1, ..., i''$ are locations of Chain A's existing stores, and $i=i''+1, ..., M$ are feasible sites for Chain A. Further, consider that Chain A is contemplating opening p new stores at time t_A. Then the optimal locations of these p stores can be found by solving the following combinatorial problem, which we call Problem P1:

$$MAX \sum_{k=t_A}^{T} \sum_{i=i'+1}^{M} \sum_{j=1}^{N} \frac{(D_{jk}A_{jk}C) - F_{ik}Z_i}{(1+r)^{k-t+1}}$$

Subject to:

$$\sum_{i=i''+1}^{M} Z_i = p$$
$$Z_i = 1 \; for \; all \; i = 1,2,...,i''$$
$$\sum_{i=1}^{M} A_{ij} = 1 \; for \; all \; j = 1,2,...,N$$
$$\sum_{j=1}^{N} A_{ij} \leq NZ_i \; for \; all \; i = 1,2,...,M$$
$$Z_i = 0, \; 1$$

The objective function of P1 maximizes the discounted value of A's profit from each of the stores in the chain. Recall that A_{ij} is the proportion of demand from j assigned to i and Z_i is equal to one if an outlet is located at site i. The first constraint dictates that A opens p new facilities and that these are located at the feasible sites. The second constraint specifies the existing locations. The next two constraints ensures that all the demand in a zone is assigned and that no demand is allocated to a node without an open facility. To solve P1 a rule for determining A_{ij} --the allocation rule-- must be specified. For example, if consumers are distance minimizers and visit their closest facility, then:

$$A_{ij} = 1 \text{ if } d_{ij} = \min(d_{ij} \mid \text{all } i \text{ for which } Z_i = 1)$$

$A_{ij} = 0$ otherwise

where d_{ij} is the shortest distance between i and j. Alternatively, probabilistic allocation rules based on spatial interaction principles can be used.

To determine its best reactive strategy Chain A solves P1 for different values of t_A, and selects the t_A and the corresponding set of locations that maximizes the chain's payoff. Note that both the optimal time and the optimal locations must be determined simultaneously, since the choice of one may affect the choice on the other.

ΓA_3 & ΓB_3: Finally, what is A's expected payoff if it enters the market during period t? The payoff will depend on B's response to A's preemptive move. Let B's optimal strategy be to respond at time t_B. Then A's payoff can be written as follows:

$$\Gamma A_3 = \sum_{k=t}^{t_B-1} \frac{RA_k(+1)}{(1+r)^{k-t+1}} + \sum_{k=t_B}^{T} \frac{RA_k(2)}{(1+r)^{k-t+1}} \tag{7}$$

The first component of Equation (7) is the discounted value of A's profits from t to t_B - 1, the period during which it has an advantage in the market. The second part of the equation sums A's discounted profits from t_B onwards. We can similarly write chain B's payoff as:

$$\Gamma B_3 = \sum_{k=t}^{t_B-1} \frac{RB_k(-1)}{(1+r)^{k-t+1}} + \sum_{k=t_B}^{T} \frac{RB_k(2)}{(1+r)^{k-t+1}} \tag{8}$$

Since Firm A's payoff from entering the market during time t depends on how Firm B reacts, it has to consider numerous contingencies in selecting its optimal strategy. The indeterminacy is resolved, however, by assuming that Firm B will respond by selecting the strategy that maximizes its own conditional payoff. Thus A can anticipate B's move by putting itself in the competitor's shoes. To determine its optimal reactive strategy chain B will maximize ΓB_3, by selecting the optimal time and locations. To determine the best location and time combination Chain B now has to solve Problem P1, given A's entry at time t. If Chain A enters the market at time t and chooses the locational configuration A_p, the competitor solves the following problem:

$$\underset{B_q, k>t}{Maximize}\ \Gamma B_3(B_q, k \mid A_p, t) \tag{9}$$

where B_q is the set of sites at which B should locate its outlets, and A_p the set of sites selected by A.

Chain A's payoff from entering the market at time t, given particular values of p and q, can now be found by solving the following problem (Problem P2):

$$\underset{A_p, t}{Maximize}\{\Gamma A_3(A_p, t \mid B_q^*, k^*)\ [\underset{B_q, k}{Max}\ \Gamma B_3(B_q, k, \mid A_p, t)]\}$$

The result to this optimization problem determines the locations at which Chain A should locate its stores at time period t, the optimal time of Chain B's response, the optimal locations for chain B, and consequently, A's payoff from entering the market at time t.

Computing Optimal Strategies

Solving problems P1 and P2 analytically is computationally difficult when a large number of time periods and feasible sites have to be considered. To solve these problems we use a combination of exhaustive search and vertex substitution methods based on the solution procedure for competitive location models suggested by Craig and Ghosh (1984). A number of procedures are available for solving Problem P1 for any given time period. For example, for a given value of k the objective function of P1 can be maximized by using vertex substitution algorithms such as the one suggested by Teitz and Bart (1967). The vertex substitution algorithm determines the optimal sites for the stores, if the chain is committed to enter the market at time k. We use the algorithm to solve P1 for different values of t_A. A comparison of the objective function values across time periods allows us to determine the overall solution to Problem P1. To solve Problem P2 we follow Ghosh and Craig (1984), who suggest a procedure for solving P2 --that is finding the optimal sets A_p and B_q-- for a fixed pair of times t and k. As before, we incorporate their procedure in an iterative algorithm and search over all possible combinations of t and k to determine the solution to P2. Because of our use of the vertex substitution procedure to determine locations, global optimality cannot be guaranteed. Previous experience with the Teitz and Bart algorithm, however, has shown it to be very robust and one that typically results in the optimal or near-optimal solutions (Rosing, Hillsman, and Rosing-Vogelar 1979).

Model Illustration

To illustrate its application the model was applied to the data set shown in Figure 1. The market area was divided into 47 customer zones and the population within each zone was estimated from secondary sources. The pattern of future population growth in each zone was also projected based on information on new building construction and other related trends. Although not shown in Figure 1 there is considerable spatial variation in expected growth. In general, zones in the southeast were expected to grow faster than the rest of the area. A number of feasible sites for new store locations were also identified based on land availability and zoning restrictions. However, as shown in the Figure, some of these sites were not expected to be available until time period 8. It is assumed that only one outlet can be located at each feasible site and that both chains are restricted to this set of sites. The distance between the centroid of each zone and each feasible site was calculated based on the existing road network. There are three convenience store outlets in this market operated by two chains. Chain A operates two of the stores and the third one is operated by Chain B.

To calculate store profits we assume that the annual family budget for convenience purchases is $3,500 and the gross profit margin on sales is 5 percent. In addition, each store incurs an annual fixed expense (rent or cost of capital) of $18,000. Both firms have a planning horizon of 10 periods and they make decisions in a sequential manner so that Chain A's decision periods are $t = 1, 3, 5, ..., 19$ and Chain B makes decisions during periods $t = 2, 4, 6, ..., 20$. Both firms are assumed to use a discount rate of 10 percent. The economic life of the facilities extends ten time periods beyond the last decision period. For expositional clarity we have purposely kept the problem scenario somewhat simple, yet it is realistic. In practice a number of factors could make the decision scenario more complex. For example, budgets, expenses and margins could vary over the market area, and firms could have planning horizons of different lengths or use different discount rates. The problem formulation can easily be extended to accommodate such differences without affecting the solution procedure.

The key feature of any locational model is the relationship between the performance of a facility and its location. Estimating this relationship requires an understanding of how demand in the area is allocated among the different facilities and how this allocation changes with the relative location of facilities. As indicated earlier, any allocation rule (probabilistic or deterministic) can be used in the proposed solution procedure. For the purpose of this illustration we assume that consumers are distance minimizers and patronize the outlet closest to them. However, unlike the classic p-median problem, we assume that the actual amount spent by each consumer decreases the further they are from their closest outlet. Thus, demand is elastic with respect to distance to the closest outlet; this implicitly assumes the existence of a more generic form of competition from other types of outlets. The less accessible the network of convenience stores, the more consumers shift their patronage to other types of outlets. The total expenditure originating from zone j at time t, D_{jt}, is given by:

$$D_{jt} = (P_{jt} a_{jt} d_{ij}^{-u}) \tag{10}$$

where P_{jt} is the number of families in zone j at time t; a_{jt} is the budget at time t, d_{ij} is the shortest distance between i and j; and u is the distance exponent, which is set to 0.5 for this illustration. We can thus rewrite Q_{it}, the profit at location i during time t as follows:

$$Q_{it} = \sum_{j=1}^{N} [(P_{jt} a_{jt} d_{ij}^{-u}) A_{ij} C_i - F_{it}] \tag{11}$$

where A_{ij} = 1 if j is the closest facility to i and zero otherwise. Note that by virtue of Equation (10) the location game is not a zero-sum game. The firms can increase total expenditures in the area by expanding their network of outlets or by making them more accessible.

Optimal Time of Entry and Location

The results of applying the solution procedure described in the previous section to our data set is shown in Table 1. The table shows, for each time period, the optimal decision for the firm. At each time period a firm may elect to wait or preempt the market. If it is better for the firm to preempt, the table shows the optimal location for the new facility and the optimal reactive strategy for the competitor. For example, in time period 1 it is best for firm A to wait and not preempt the market, even though it clearly has the opportunity to do so. Waiting is also the best strategy for Chain A during time period 3. Chain A's strategy of not preempting the market at the first opportunity reflects the dynamics of demand evolution in the market. Because of the slow growth in the market during the early time periods, any outlet opened during the first and third time periods would not generate enough revenue to cover the cost of establishing and operating those outlets.

By the fifth time period the growth in demand is large enough to make it profitable for Chain A to enter the market. If Chain B has not already entered the market, A should preempt the market and locate a facility at site 17. Chain B's best reaction to this strategy is to enter the market at the next time period and locate a facility at site 10. If firm A misses the opportunity to preempt the market during the fifth time period, its next profitable opportunity to preempt the market is at t=11, assuming that Chain B does not preempt during the mean time. If Chain A enters at t=11, the new outlet should be opened at site 22. Firm B's best response is to open a facility at site 10 during time period 12. It is not profitable for Chain A to enter the market at any time period after t=11.

Table 1 also shows the decisions from Firm B's perspective. The earliest Chain B can profitably preempt the market is during the fourth time period. The optimal location is at site 8. Chain A's best response is to open a new outlet at site 11 during the seventh time period. Firm B can also preempt the market during t=6, 8, 12 and 14. Note, however, that B's optimal locations as well as A's best reaction changes with time. This again reflects the spatio-temporal pattern of demand growth and the availability of feasible sites. Overall Chain B has more incentive to preempt the market, because it currently has only one facility while Chain A has two.

The results provide a sequence of optimal decisions that the firm's should follow at each time period. Chain B has the first opportunity to profitably preempt the market at t=4. If it behaves optimally, it will take up this opportunity to enter the market and locate the new outlet at site 8. By locating the new outlet at site 8 the chain increases its accessibility to consumers in the eastern half of the region. It also creates significant competition for Chain A's existing outlet at site 4. Having been preempted, Chain A has to decide how it is going to react to B's move. The optimal reaction strategy is to locate an outlet at site 11 during the seventh time period. An outlet at this site helps the chain to establish a foothold in the growing southeastern area and reduce, at least partially, the impact of B's new outlet at site 8. Why doesn't Chain A react to Chain B's preemption at t=5 or preempt the market itself during the first or the third time periods? The reason in both cases is the pattern of demand evolution. The growth rate in the southeastern zones is expected to accelerate only after t=5. A new outlet at site 11 will not be profitable if it is opened earlier than t=7. Since the firms' objective is to maximize discounted profits, losses during early time periods reduce overall profitability. Thus, if both firms behave optimally, the market will evolve as follows: Chain B will preempt the market by opening a new facility during time period 4 at site 8. Chain A will respond to B's actions by opening an additional facility at site 11 during the seventh time period.

If for some reason (for example, lack of access to capital) Chain B forgoes the opportunity to preempt the market during t=4, it is advisable for A to preempt the market during t=5 by locating at site 17. Chain B's optimal reaction in this case is to locate a facility at site 10 during the next time period. Note that the locational choices differ depending on whether the firm is preempting the market or reacting to its competitor's preemptive move. Thus, Chain B reacts to A's entry by locating its outlet at site 10 instead of site 8, which is the optimal preemptive location. Site 10 is approximately equidistant between the sites 4 and 17, thereby enabling Chain B to compete with both of Chain A's outlets. If Chain B reacted with an outlet at site 8, A's outlet at 17 would have a virtual monopoly in the east.

The results shown in Table 1 enable us to demarcate the planning horizon into zones with differing levels of competitive activity. Periods one to three, for example, are a zone of comparative lull. Neither firm has an incentive to enter the market during these time periods. Time periods t=4, 5, and 6, on the other hand, are periods of intense rivalry, since it is optimal for both firms to try to preempt the market during these time periods. After the sixth time period there is a five period hiatus for firm A, during which it is not optimal for it to enter the market. Only Chain B has an incentive to enter the market during this time. This is followed by a short span during which both firms have an incentive to enter the market. After time period 14 neither firm has any incentive to enter, since the cost of entry cannot be recouped during the rest of the planning horizon. Thus if no firm enters by t=14, the market will be served only by the three existing outlets.

The profit maximizing strategy for each firm is to preempt the market at the very first period it is profitable for it to do so (i.e., period 4 for firm B and period 5 for Chain B). If the market is already preempted by the competitor then the firm should implement its best reactive strategy. Thus, in this example, the likely pattern of market evolution is that Chain B will enter the market during time period 4 and open its new outlet at site 8, and Chain B will react by opening its outlet at site 11 during time period 7. It is not profitable for Chain A to be the first one to add the new outlet, it should follow B rather than preempt it. Note that this decision to follow rather than lead evolves from the results of the model application rather than being exogenously specified.

Model Extensions

The general application of the model can be extended in a number of ways. The results in Table 1 are based on the assumption that each firm locates only one new outlet. One extension to the present framework is to allow one or both firms to locate multiple outlets. Firms may make multiple location decisions in one of three ways. First, all new outlets may be opened during the same time period. Second, firms may open new outlets during different time periods. The third is a more general approach in which firms have the choice of locating all outlets during one time period or at different times. We use the last approach because it encompasses the first two.

Consideration of multiple outlets and entry periods increases the computational effort required. Suppose each firm is planning to locate two outlets. In determining its optimal strategy for entering the market the firm has to anticipate the impact of its second move and the competitor's second reaction, in addition to anticipating the competitor's reaction to the first entry. At any decision period the firm has to decide between : (i) not locating any new outlets during that time period (W); (ii) opening one store now and one store later (G1); and (iii) opening two stores now (G2). In choosing among these strategies the firm has to consider the competitor's likely reactions to each of these strategies. If the firm decides to wait, the competitor can either wait (W), build one outlet the next period and one later (G1), or build two (G2). On the other hand, if the firm chooses either G1 or G2, the competitor can react to each of these strategies with its own G1 and G2 strategy. The firm's optimal decision depends on the payoff associated with each strategy.

Table 2 shows the payoff matrix for Chain B's decisions at $t=4$ and Chain A's reaction at $t=5$. The figures in each cell show how the payoffs for the two firms vary with their respective strategies. Chain B's payoff is shown in the upper left of each cell and Chain A's on the bottom right. For example, if B waits (W) at $t=4$ and A opens two new outlets at $t=5$, B's discounted profit for the rest of the planning horizon will be $0.56m, while A will gain $2.76m during the same period. Note that this $0.56m payoff for Chain B is contingent on the firm reacting in the optimal manner at some future decision period. That is, if it does not preempt the market at t=4 and Chain A locates two new outlets at t=5, Chain B can never earn more than $0.56m. It may earn less if it does not react optimally in the future.

It is apparent from inspecting the payoff matrix in Table 2 that Chain B's best strategy at t=4 is G1 -- open one outlet now and one later. Chain A will also respond with a G1 strategy --it will open one new facility at t=5 and another at t=9. This is the minimax strategy. The respective payoffs for B and A are $2.22m and $1.79m. The G1 strategy implies that the chains open two new stores, but not at the same time. Chain B's payoff amount of $2.22m is contingent on the second store being located optimally and opened at the correct time. In this scenario the best time for Chain B to open its second outlet is t=8 and the best locations for the two new stores are sites 8 and 22, respectively. Chain A's optimal response is to open one outlet at site 11 at t=5 and one at site 21 at t=9. If A deviated from this response, Chain B can expect a payoff higher than $2.22m and Chain A's payoff will be less than $1.79m. To specify the decision rules for the firms at each time period, payoff matrices like the one shown in Table 2 must be calculated for each decision period and the minimax strategy identified. The optimal decisions for both firms at each time period are shown in Table 3.

As in the one outlet case, Firm B has the first opportunity to preempt the market. It can preempt the market at t=4 and open a new facility at site 8. This part of its strategy is similar to the optimal one facility strategy. But in this case the store opening at t=4 is to be followed by another facility at site 22 at t=8. As noted before Chain A's optimal response is to locate its first new facility at site 11 at t=5 and the second one at site 21 at t=9. Although firm B has the option to enter the market with two new facilities at the same time, it does not do so. This is because site 22 is not available till period 8 and the currently available sites do not serve enough demand to justify a second store.

It is important to note that when the firms plan to open more than one facility, the location and timing decisions for all stores are mutually dependent. Thus, although Chain B's optimal strategy does not call for opening the outlet at site 22 until time period 8, the location and timing of this opening is crucial to the success of Chain B's overall strategy. This implies that negotiations for the two sites should be conducted simultaneously and the rights to open the second store during time period 8 secured when the first store is opened. It is possible that if a chain is unable to open the second store at its optimal site and at the optimal time and is consequently forced to select a different site, the location of its first outlet may become suboptimal too. In designing their locational strategies, it is imperative, therefore, that firm's consider their network of outlets in its entirety rather than look at each store separately.

It should be noted that the comparison of the G1 and G2 strategies is only a comparison between opening one store immediately followed by one later or opening two stores immediately. In order to decide whether to open two stores at all, Chain B should compare the maximum of the G1 and G2 strategies with the maximum profit obtainable by opening only one store. Using the same logic, the model could be run iteratively for different numbers of stores, allowing the firms to choose the most profitable overall strategy.

One implicit assumption in our model is that each site has an identical cost. Of course, in reality this is unlikely to be the case with the more attractive sites commanding a rent premium. It is not a difficult matter to incorporate spatial variations in rents into the current model. This is done by letting the fixed costs F_i vary with location. The approach proposed here allows a firm to calculate the maximum rent premium for a given site as a function of the opportunity cost of losing access to the site. For example, if, for some reason, site 8 was not available to Chain B at time period 4, its next best option is to open at site 7 (A's best response is still to open at site 11 at time 7). Shifting the outlet from site 8 to site 7 will reduce Chain B's profit by 5 percent. Thus, it can afford to offer some portion of this incremental profit as a rent premium for site 8. Following this same logic Chain A too can calculate the amount it can afford to spend in trying to foreclose site 8 and deny it to Chain B.

Our proposed approach can also be extended to deal with situations in which firms are asymmetric. In the current illustration it is implicitly assumed that both firms have equal ability to draw customers. It could be the case, however, that customers may be loyal to one chain because of its image or other store attributes. This can be easily incorporated into the procedure by modifying the allocation rule. Similarly, asymmetries in costs and margins between firms can be incorporated by specifying Equation (6) separately for each firm. Our suggested procedure is able to handle these and other sources of asymmetries, as long as these asymmetries are known to both parties in the game.

Conclusions

The selection of good locations is often the most important part of a successful retail strategy. Given the importance of this decision a number of retail site selection models have been proposed by previous researchers. Although these models have made a significant contribution to the literature, the issue of optimal timing and the question of market preemption in competitive markets have been largely ignored. The model we propose allows a firm to develop a coherent locational strategy by simultaneously considering the issues of *how many* stores to open, *when* to open them and *where* to locate them. Further, the model incorporates a dynamic, competitive setting where the attractiveness of a given site depends on the past actions of the firms, likely demand growth patterns and future competitive reactions. Thus this paper serves to integrate the literatures on competitive location strategy by modeling the location and timing dimensions within a single decision framework.

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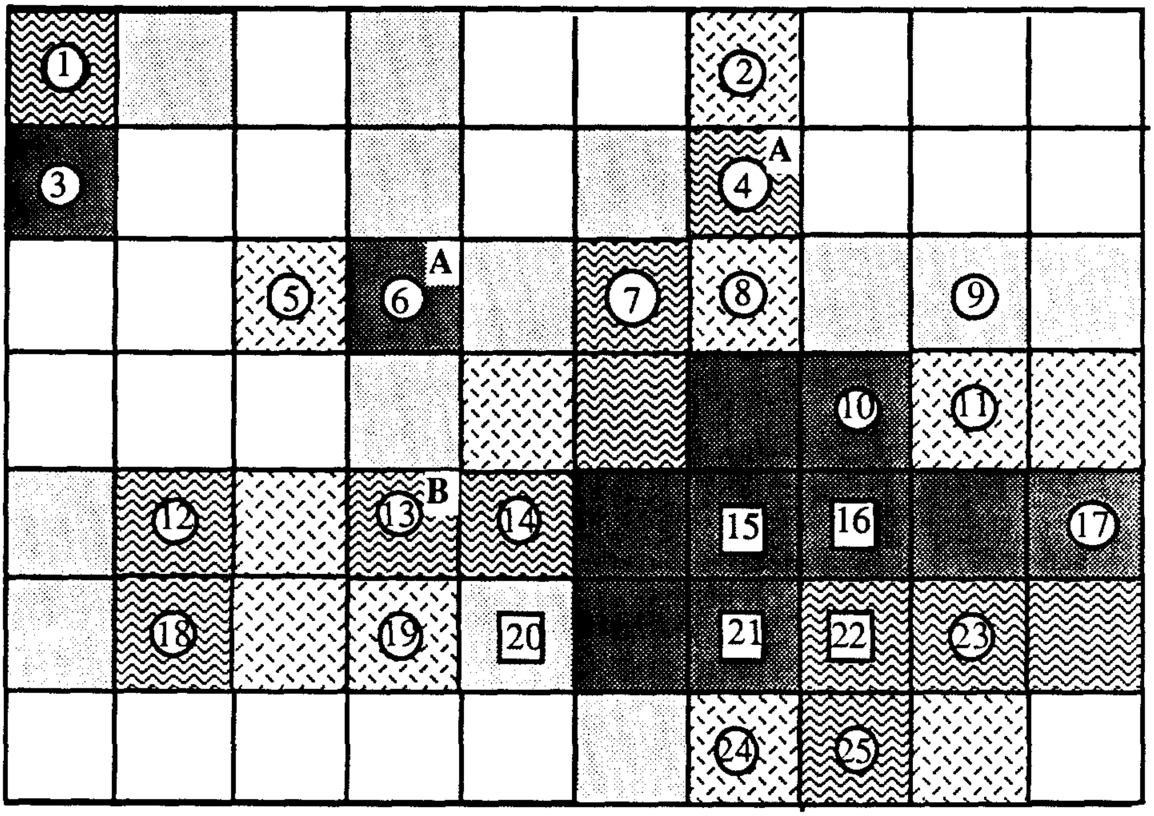
Figure 1

Map of the Study Area



non-residential areas

less than 400 pop.

400 to 1.100 pop.

1,101 to 2,200 pop.

pop. > 2,200

Feasible sites available at start of planning horizon

Feasible sites available from t=8

A(B) Chain A's (B's) existing outlet

Table 1

Optimal Timing and Location

Time	A	B	Optimal Reaction
1	Wait	-	-
2	-	Wait	-
3	Wait	-	-
4	-	8*	11_7**
5	17	-	10_6
6	-	8	22_{11}
7	Wait	-	-
8	-	22	17_{11}
9	Wait	-	-
10	-	Wait	-
11	22	-	10_{12}
12	-	22	21_{15}
13	Wait	-	-
14	-	22	21_{15}
15, 17, 19	Wait	-	-
16, 18, 20	-	Wait	Wait

* locate at Site 8 at t=4

** A's optimal reaction is to locate at Site 11 at t=7

Table 2

Payoff Matrix at t=4

B 's decision at t = 4	A's decision at t = 5: Wait	G1	G2
Wait	1035 1362	979 2984	566 2764
G1	not applicable	**2221** **1790**	2001 1116
G2	not applicable	1986 1279	476 322

Table 3

Optimal Timing and Entry with Multiple Locations

Time	A	B
1	Wait	-
2	-	Wait
3	Wait	-
4	-	$8, 22_8$*
5	$17, 22_9$	-
6	-	$8, 17_6$
7	$23, 18_9$	-
8	-	$22, 9_{10}$
9	$16, 22_9$	-
10	-	$22, 9_{12}$
11	Wait	-
12	-	$22, 9_{12}$
13	Wait	-
14	-	$22, 9_{14}$
15, 17, 19	Wait	-
16, 18, 20	-	Wait

* read as: open first outlet at site 8 and the second at site 22 at t=8

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