1976

Modelling Human Spatial Behavior in Urban Recreation Facility Site Location

M. F. Goodchild

P. J. Booth

Discussion Paper 007

MODELLING HUMAN SPATIAL BEHAVIOR IN URBAN RECREATION FACILITY SITE LOCATION

M. F. Goodchild*

P. J. Booth†

RESEARCH PROGRAM: IMPACT OF THE PUBLIC SECTOR ON LOCAL ECONOMIES

Department of Economics
The University of Western Ontario
London Ontario Canada

Discussion Paper 007

MODELLING HUMAN SPATIAL BEHAVIOR IN URBAN RECREATION FACILITY SITE LOCATION

M. F. Goodchild*
P. J. Booth†

January, 1976

*Department of Geography, University of Western Ontario
†Department of Geography, McGill University

MODELLING HUMAN SPATIAL BEHAVIOR IN URBAN
RECREATION FACILITY SITE LOCATION

M. F. Goodchild
P. J. Booth

Abstract

This paper is about the planning of urban recreation facility locations. It examines the provision and the use of public recreation facilities within an urban area, as exemplified by the set of public swimming pools in London, Ontario, by developing a model which incorporates expressed spatial behavior and predicts potential usage of a set of facilities. These two components are then used in an objective procedure for selecting and evaluating new sites for the location of public facilities. This model is considered to have a behavioral base because it incorporates the responses of users to the spatial configurations of supply within the system in a predictive interaction model. Parameters for the models are derived from the empirical observation of users.

MODELLING HUMAN SPATIAL BEHAVIOR IN URBAN
RECREATION FACILITY SITE LOCATION

M. F. Goodchild
P. J. Booth

1. Background

In recent years a number of researchers have suggested that a key focus should be the area of urban recreation, and increasing demand for both facilities and open space. Problems of accessibility to recreation areas centre on what Wolfe (1964, p. 216) has identified as the two main factors in this research, people and spatial imbalance, involving the movement of people from the places where they live to the places where the facilities are located.

Recent efforts have been aimed at developing predictive models which can be used in the urban environment. (See, for example, Dee and Liebman, 1970). Many of these have centred on the gravity model concept. Mueller and Echelberger (1973, p. 5) have indicated that the systems approach to forecasting recreation consumption for a site, complex or region, can provide the flexibility needed to incorporate the many complex relationships that underlie the process. Beaman and Leicester (1970) attempted to develop what may be considered a systemic model of participation in an urban area. This model also attempted to take into account the interaction effects of competing facilities on patterns of use. Such approaches typify the few attempts which have been made to apply the predictive and systematic modelling concept to recreation patterns and hence facility operations. Beaman (1973, p. 1) has stated that a major problem in the practical evaluation of recreation programs has been a failure to recognize the effect that characteristics of a population and the existing recreation system have on the design of facilities and their location.

The field of recreation planning is conspicuous by its reliance on traditional standards and methods. Sessoms (1964) however has shown a need to re-evaluate many of the traditional viewpoints and standards used by planners in establishing recreation facilities. While the provision of space standards for facilities is incorporated into most official plans, consideration must also be given to accurate and realistic assumptions concerning users. Not only must facilities be provided but the accessibility and mobility factors affecting potential users must also be incorporated into locational decisions.

A number of problems arise in practice when the issues of accessibility and location of facilities are not fully appreciated. Gold (1972) and Bangs and Muhler (1970) have examined non-use of facilities within this context. Gans (1969), Porteous (1971) and Dee and Liebman (1970) have indicated the need for planning for people using firmer assumptions about behavior and desires.

To date the primary tool used in planning for recreation has been the planning standard. The development of such standards has been traced to the 1890's. Facility concepts were developed, such as square feet required per user, service radii such as ¼ mile for a playground, and approximate sizes of neighbourhood facilities. These are largely an historical estimate of expert opinion, developed in another country in 1900 (Shivers and Hjelte, 1971, p. 210). These standards had very little real basis in terms of observed behavior and scientific evaluation. Shivers <u>et al</u>. pointed out that there is today a growing need for a new set of criteria which incorporate the results of experimentation in such areas as human behavior, to provide more precise answers to questions concerning recreation facility planning.

This paper tackles two major problems: the description and explanation of individual consumer behavior, and the use of such information in the selection of recreation sites. Both elements exist in the traditional service area approach, but are treated in a manner which, although simple and easy to apply, too often departs substantially from reality. Yet while the recreation planner would welcome a more accurate approach, he is understandably wary of the volume of data required, and of the increased complexity of the corresponding models. Thus if the circular service area is to be replaced by an accurate model of trip patterns, it is essential that the new model achieve the maximum explanation with the minimum of complexity, that it be based on clear hypotheses and that the model be as general as possible.

2. Data Collection

The city of London, Ontario has a comprehensive system of public recreation facilities. The Department of Recreation operates eleven public swimming pools between the months of June and September as part of their summer program. These facilities are all outdoors and of uniform size and attract upwards of 20,000 users per week.

Inverviews were conducted at the eleven existing swimming pools during the summer of 1973. A 10% random sample of one day's users was interviewed at each of the eleven sites. These interviews were then aggregated to give a 10% sample of the matrix of daily flows between the 460 Enumeration Areas in the city, and the eleven pools.

The data from the on-site interviews were used in three stages of analysis. Stage I dealt with the expressed demand; stage II combined demand and supply to model the interaction taking place within the system. Stage III of the model utilized information obtained in stages I and II in a procedure designed to evaluate the location of existing sites and proposed new sites. The model, then, examined the present operation of a recreation system, predicted levels of potential use for hypothetical arrangements of supply and demand, and approached the problem of facility location for that potential.

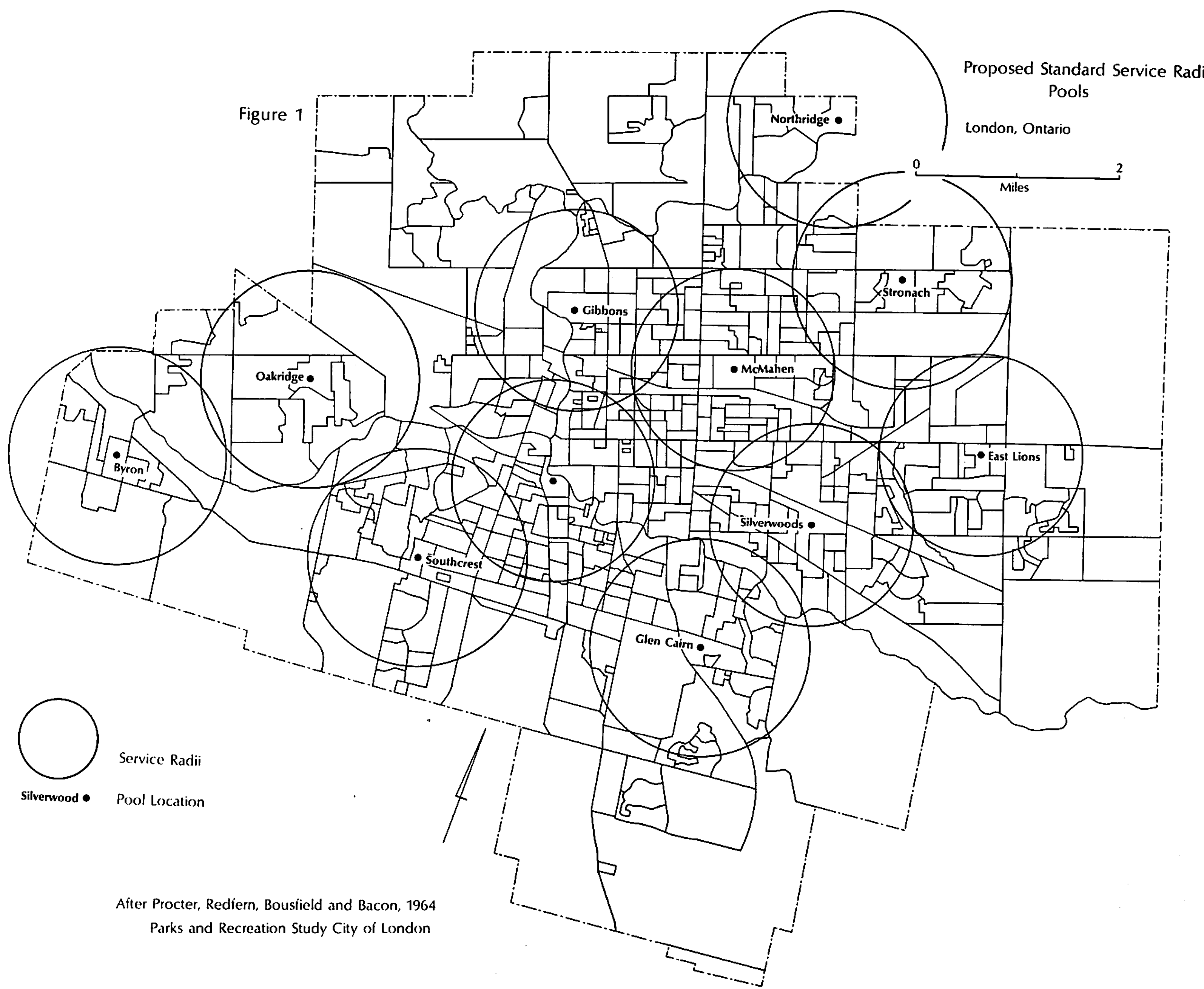
The stage III analysis is applied specifically to the question of the optimum locations for two new pools which have recently been proposed for the London system by the Public Utilities Commission. The problem is complex, since the flow of users to locations clearly depends on those locations, and also on the locations of all alternative destinations.

3. The Observed Pattern of Demand

Traditional approaches to the spatial pattern of use for recreation facilities have centred on the concept of service radii. Figure 1 presents the typical service radii of 1 - 1.5 miles. The observed data are presented in Figure 2, which was constructed by linking the outer set of users for each facility to form a convex boundary around each site.

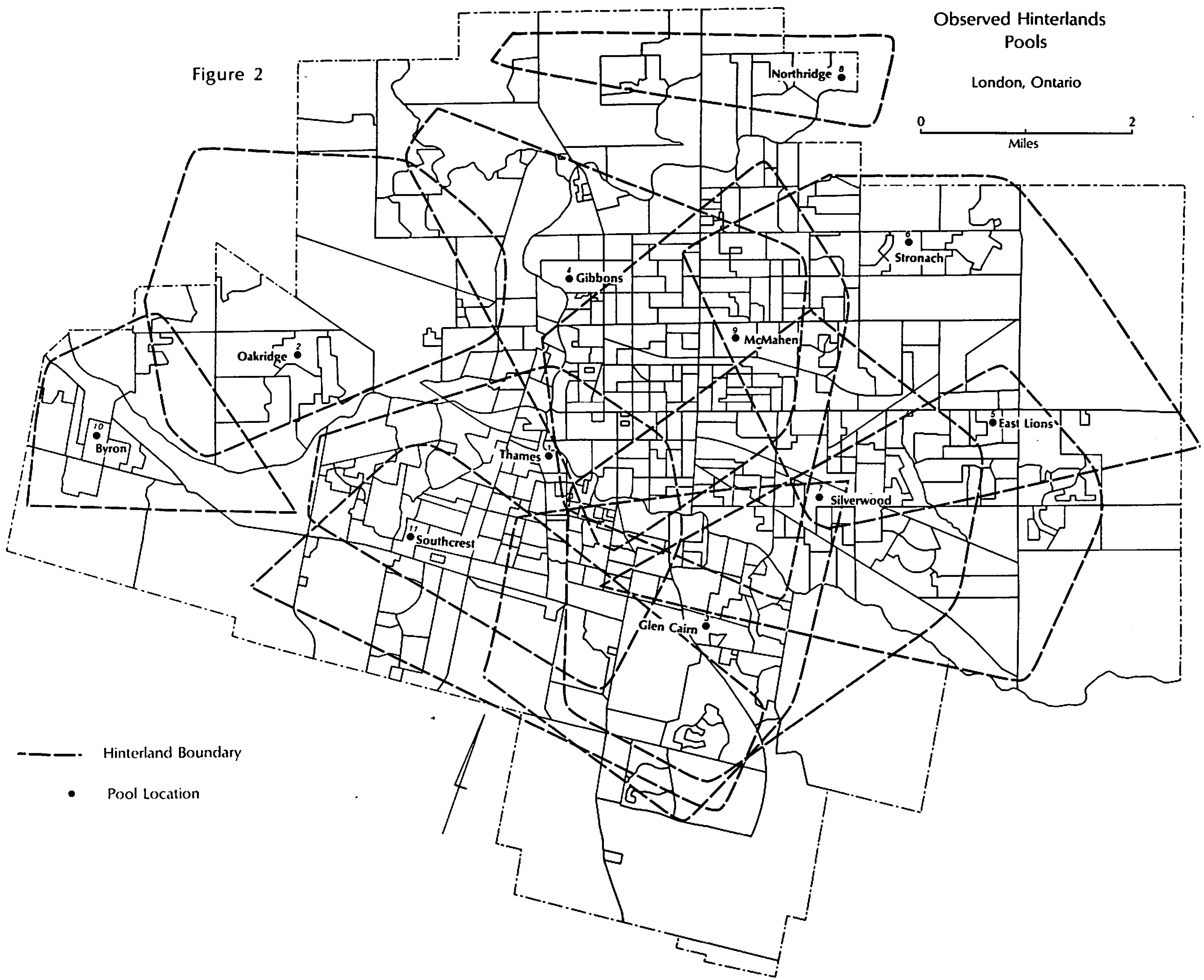
The most obvious difference between the two figures is the much greater degree of overlap between service hinterlands of the observed demand pattern. While the service radii overlap to some extent wherever two pools are within 1.5 miles of a home, distance is clearly the major determinant of the service areas. In the real situation, it is clear that users will frequently travel much further than is necessary to use a pool. The role of distance as the determinant of spatial choice is complicated by other factors attributable either to the facilities or to the users.

Figure 1



After Procter, Redfern, Bousfield and Bacon, 1964
Parks and Recreation Study City of London

Figure 2


Observed Hinterlands
Pools
London, Ontario
0
2
Miles
Northridge
8
Stronach
6
Gibbons
4
McMahen
9
Oakridge
2
East Lions
5
Byron
10
Thames
1
Silverwood
7
Southcrest
11
Glen Cairn
3
Hinterland Boundary
Pool Location

Some hinterlands are much more compact and isolated than others. Pools 2, 8 and 10 show much less overlap, suggesting that for these facilities there is little to complicate the effect of distance as the determinant of spatial choice.

The figures illustrate the fundamental complexity of any spatial choice process. The flow of users between a residential area and a facility is affected by the length of the trip, the nature of the facility and the demographic structure of the area, and also by the existence of other alternative facilities, and by the flows from other residential areas in the system. The next sections will discuss the formulation and calibration of appropriate models.

4. The Interaction Model

Consider an individual in Enumeration Area, or origin, i, in the process of choosing between two recreation sites j and k, out of the total set of 11. The Luce choice axiom (Luce, 1959) would mean in this context that the ratio of the likelihoods of choosing j or k out of the available set is independent of the size of the set, and of the individual's feelings about the other alternatives. This is the Principle of Irrelevant Alternatives: the relative likelihoods of choosing j and k will remain constant whatever the alternatives to them.

Figure 3 gives a simple illustration of the principle. In situation (a) a potential user at location A has two alternative sites to choose between, _j_ and _k_. His preferences are such that the probability of choosing _k_ is three times that of choosing _j_, so that because these are the only available alternatives, the probabilities of visiting _j_ and _k_ are .25 and .75 respectively.

In situation (b) a third site _i_ is introduced. Suppose that its

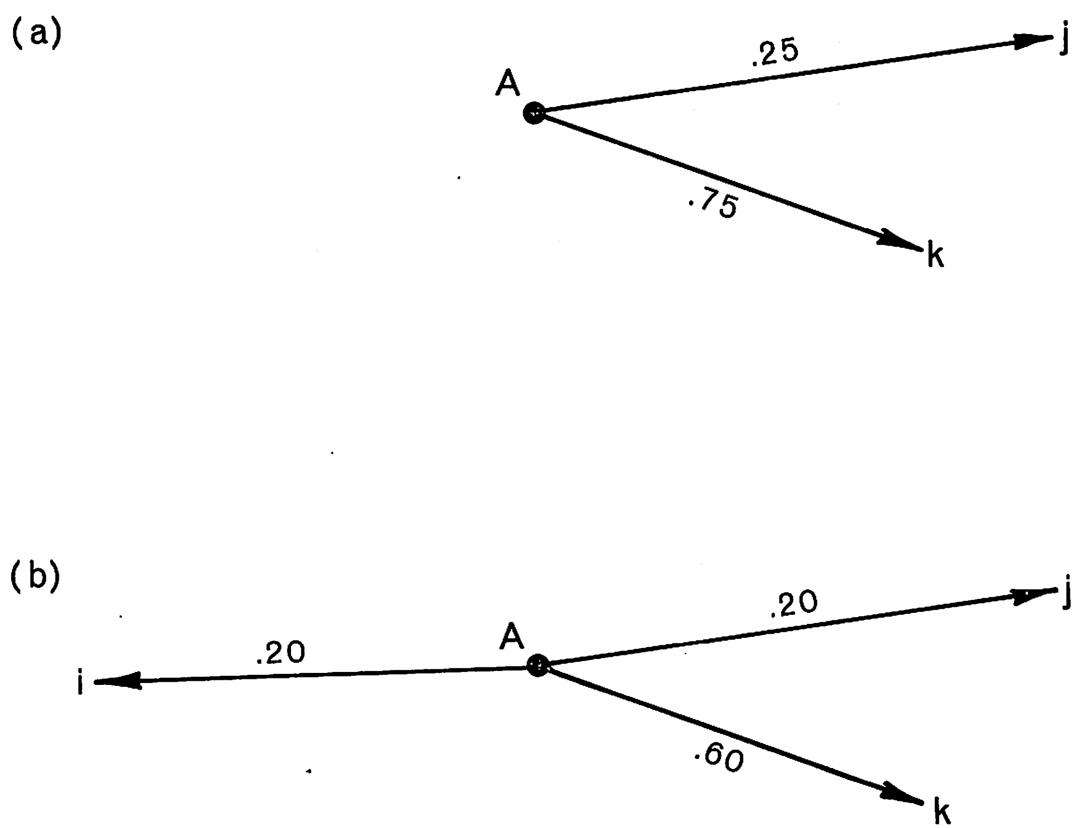


Figure 3
Application of the Principle of Irrelevant Alternatives

probability is .20. The choice axiom requires that the remaining .80 be divided between j and k in the same ratio as before, so that the probabilities become .20 and .60 respectively. Thus the ratio of j's probability to k's will be 1:3 irrespective of any alternative sites offered to the user.

Assume now that two variables enter into the choice decision by affecting the individual's preference for some site j; the attraction of the site A_j and the distance to the site D_{ij}. Attraction is interpreted as embodying such elements as size, facilities offered and the level of crowding anticipated by the individual.

These two assumptions allow us to write the probability that an individual will select site j out of the available set of n sites as

$$P_{ij} = f(A_j,D_{ij})/\sum_{k=1}^{n} f(A_k,D_{ik})$$

Assuming that in Enumeration Area i, E_i people will participate in this particular activity, we have

$$I_{ij} = E_i \; f(A_j,D_{ij})/\sum_k f(A_k,D_{ik})$$

The term $\sum_k f(A_k,D_{ik})$ is an alternatives factor, since it ensures that the flow to each existing site will diminish when a new site is added to the system.

In this research, the function f(A,D) has been taken as A/D^b where b is a fitted parameter; the model now resembles the standard gravity model with an alternatives factor, or the 'production-constrained' model;

$$I_{ij} = \frac{E_i \; A_j/D_{ij}{}^b}{\sum_k A_k/D_{ik}{}^b}$$

with the A's interpreted as unknowns to be fitted from empirical data, along with the E's and b. But unlike the classic equation, this model is based on clear principles of individual behavior.

The term b represents the importance of distance as a determinant of choice between alternatives. If b is large, distance is of great importance and users tend to ignore other factors in making decisions, so that the majority simply travel to the nearest available swimming pool. With b small, distance is subordinate to attraction in the decision process, and users will tend to reject closer alternatives in favour of more attractive, distant ones.

The A_j, or attraction terms, incorporate all of those attributes of a site, other than its location, which affect a user's choice. They are treated as unknowns in this paper, and given values which best account for the observed patterns of behavior in the system. They represent the user's assessment of such physical factors as size, age and amenities offered, as well as more endogenous characteristics like noise, crowding and cleanliness.

The distance terms D_{ij} might be measured as straight lines, or in some form more representative of the time actually taken to travel between i and j, to allow for variable congestion, travel barriers, etc. There are operational advantages to straight line distance since it can be calculated from co-ordinate locations, whereas time distances must be separately estimated for each combination of origin and destination. In this research, the straight line approach has been taken throughout since it was felt to give a satisfactory representation of the trip length between home and swimming pool. Home location was taken to be centroid of the respective Enumeration Area, a tract of land containing roughly 500 residents.

The parameters E_i represent the population of each Enumeration Area that participates in this particular recreational activity, and can be dealt with in a variety of ways. The simplest assumption investigated in this paper is that E_i is a constant proportion of each Enumeration Area population: thus,

$$I_{ij} = \frac{aP_i \; A_j/D_{ij}{}^b}{\sum_k A_k/D_{ik}} \tag{1}$$

with P and D known, and a, b, and A to be estimated from observations. However, certain age groups are much more likely to use public swimming pools than others, so that P_i should perhaps be weighted in favour of young children. The term aP_i can be replaced by a weighted summation $\sum_l a_l \; P_{il}$ where P_{il} is the population of Enumeration Area i in age group l, and a_l is the proportion of age group l participating in the activity, giving

$$I_{ij} = \frac{(\sum_l a_l P_{il}) \; A_j/D_{ij}{}^b}{\sum_k A_k/D_{ik}{}^b} \tag{2}$$

with P and D known, and a, b and A to be estimated.

In both models (1) and (2) the demand from each Enumeration Area is fixed, and independent of the number of alternatives offered. Thus if new pools are introduced into the system, the effect is to divert users from existing sites, by increasing the denominator term, leaving the total use constant. In many recreation situations this is inappropriate; the introduction of new sites will divert existing users, but also increase total demand by encouraging previous non-users to participate, either by providing new, closer and more attractive alternatives, or by reducing crowding at existing sites and thus increasing their attraction.

This effect might be dealt with in various ways. The a terms in both models might be made functions of the supply of alternatives, $\sum_k A_k/D_{ik}{}^b$. Cesario (1974) has examined models of the form

$$I_{ij} = E_i\ A_j/D_{ij}^{\ b}$$

in which E_i is a fitted parameter which can be compared to the available supply at each origin in a second stage of analysis. However, since both the attraction terms $\underline{A}$ and the friction of distance affect supply, these terms appear in both stages of calibration, which raises operational problems (Ewing, 1974).

Another approach lies in regarding non-use, or staying at home, as a legitimate alternative. Consider the model;

$$I_{ij} = \frac{(\sum_{l} a_l P_{il})\ A_j/D_{ij}^{\ b}}{\sum_{k} A_k/D_{ik}^{\ b} + \delta} \tag{3}$$

$$N_i = \frac{(\sum_{l} A_l\ P_{il})\ \delta}{\sum_{k} A_k/D_{ik}^{\ b} + \delta}$$

where N_i is the number of non-users, and $\sum_{l} a_l\ P_{il}$ the total number of potential users of swimming pools, including those that choose not to participate given the present supply of alternatives. N_i is unknown, as is $\sum_{l} a_l\ P_{il}$, since not all residents will participate even with an infinite supply of alternatives, but both can be estimated once the model has been calibrated. For model (3), the values of $\underline{P}$ and $\underline{D}$ are known, while $\underline{a}$, $\underline{A}$, $\underline{b}$ and δ must be estimated from observations.

The model can be further elaborated by allowing the effect of distance to depend on travel mode in situations where several modes compete, or by disaggregating the population on more dimensions than simply age. But neither of these possibilities seem warranted here.

5. Calibration

The calibration of interaction models presents particular problems and has been the subject of considerable recent literature. The first problem concerns the method of observing flow values. Suppose for example that the model predicts that 4.0 users will travel each day from Enumeration Area i to site j. Even if the model were perfect, the observed numbers would show considerable variation from the predicted figure. Days with 3 or 6 users would be quite likely, and even days with 0 are possible. Furthermore, the amount of variation depends on the magnitude of the flow, and is much higher for large flows than for small ones. This makes the use of orthodox regression analysis invalid because it violates the assumption of homoscedasticity, or uniform error variance (Beaman, Knetsch and Cheung, 1974, Goodchild, 1975). Specifically, each observation is a sample under a Poisson distribution, with an expected error variance equal to the mean expected flow.

The presence of a summation in the denominator of each model presents additional problems because the equations cannot be transformed to linear expressions, again preventing the use of orthodox regression. Evans (1971) and Batty and Mackie (1972) have discussed the calibration of similar models against maximum likelihood criteria, using iterative methods, and Batty and Mackie give an extensive comparison of different algorithms.

The method used in this paper allowed all three models to be calibrated with the same basic procedure. The values selected for the fitted parameters were those which minimized a generalized least squares criterion with each observation weighted by its expected error variance:

$$\sum_i \sum_j (I_{ij} - I_{ij}^*)^2 / I_{ij}$$

where I_{ij}^* is the observed flow between origin _i_ and destination _j_. Thus large flows, which may be expected to show large statistical day-to-day fluctuations, are given much less weight than small flows.

An iterative method due to Powell (1965) was used to minimize the criterion. The process was time-consuming because of the numbers of observations and parameters to be fitted, although few iterations of the algorithm were required to achieve convergence. Values of the objective function for each model are shown in Table 1. There is a slight improvement from Model 1 to Model 2 to Model 3, as expected in view of the increasing numbers of parameters.

Since observed and predicted flows will never agree perfectly, except in the case of an infinitely large sample, the objective function can never reach zero. Furthermore, there is no obvious upper limit to the scale. So two benchmarks were devised to give these observed objective function values more meaning.

If the model's fit to reality is perfect, each observation's weighted contribution to the objective function will be of the order of one unit. So with 460 origins and 11 destinations, the expected value of the objective function in the case of a perfect fit is of the order of 5060. Thus all three calibrations give values compatible with the hypothesis of a perfect model.

As a second benchmark, the observed values were compared to a Null Hypothesis that the same degree of fit could have been obtained by calibrating the models with purely random data. To avoid making assumptions about the statistical distributions, hypothetical flows were generated by randomizing observed flows among destinations. Thus the set of flow figures for each origin was retained, but simply reassigned to random destinations. One hundred

TABLE 1. Calibration and Sensitivity Analysis

	Model 1		Model 2		Model 3		
Objective Function	2820		2737		2723		
Parameters	Value	Sens x 10^4	Value	Sens x 10^4	Value	Sens x 10^4	
a	0.115	9.2	-	-	-	-	Participation
a_1	-	-	.0278	0.49	.0104	.008	0 - 5
a_2	-	-	.0208	2.54	.0267	1.77	5 - 15
a_3	-	-	.0008	.016	-.0039	.062	15 - 25
a_4	-	-	-.0024	.084	.0016	.004	25 - 35
a_5	-	-	.0109	0.65	.0228	0.78	35 - 45
a_6	-	-	.0126	1.04	.0204	0.38	45 - 55
a_7	-	-	.0226	0.56	.0146	0.13	55 - 65
a_8	-	-	.0054	.068	.0042	0.12	65 +
b	1.857	21.8	1.835	20.9	1.840	19.4	Distance Power
A_1	0.81	0.47	0.88	0.71	0.83	0.52	Thames
A_2	0.43	0.46	0.45	0.45	0.47	0.41	Oakridge
A_3	1.46	0.61	1.41	0.65	1.48	0.65	Glen Cairn
A_4	1.06	0.47	1.12	0.51	1.07	0.53	Gibbons
A_5	0.85	0.38	0.72	1.54	0.81	0.41	East Lions
A_6	1.41	0.46	1.52	0.49	1.47	0.50	Stronach
A_7	1.24	0.72	1.19	0.71	1.14	0.70	Silverwood
A_8	1.08	0.23	1.09	0.24	1.04	0.24	Northridge
A_9	0.82	0.47	0.81	0.51	0.77	0.50	McMahan
A_{10}	0.75	0.15	0.72	0.16	0.85	0.23	Byron
A_{11}	1.08	0.46	1.08	0.46	1.07	0.46	Southcrest
	-	-	-	-	0.060	0.095	Non-use Option

separate simulations gave a range of values of the objective function at least an order of magnitude greater than the observed values (Figure 4). The Null Hypothesis can therefore be rejected. In summary, the observed objective function values are compatible with the hypothesis of a perfect model, and incompatible with a random, or Null Hypothesis.

6. Sensitivity Analysis

The relative importance of each parameter in each model was assessed by sensitivity analysis, by observing the effect on the objective function of an independent shift in the value of each parameter. Table 1 shows the importance of each parameter as the percentage change in the objective function resulting from a one per cent change in the parameter value. Both positive and negative shifts were applied; the tabulated values represent the average effect.

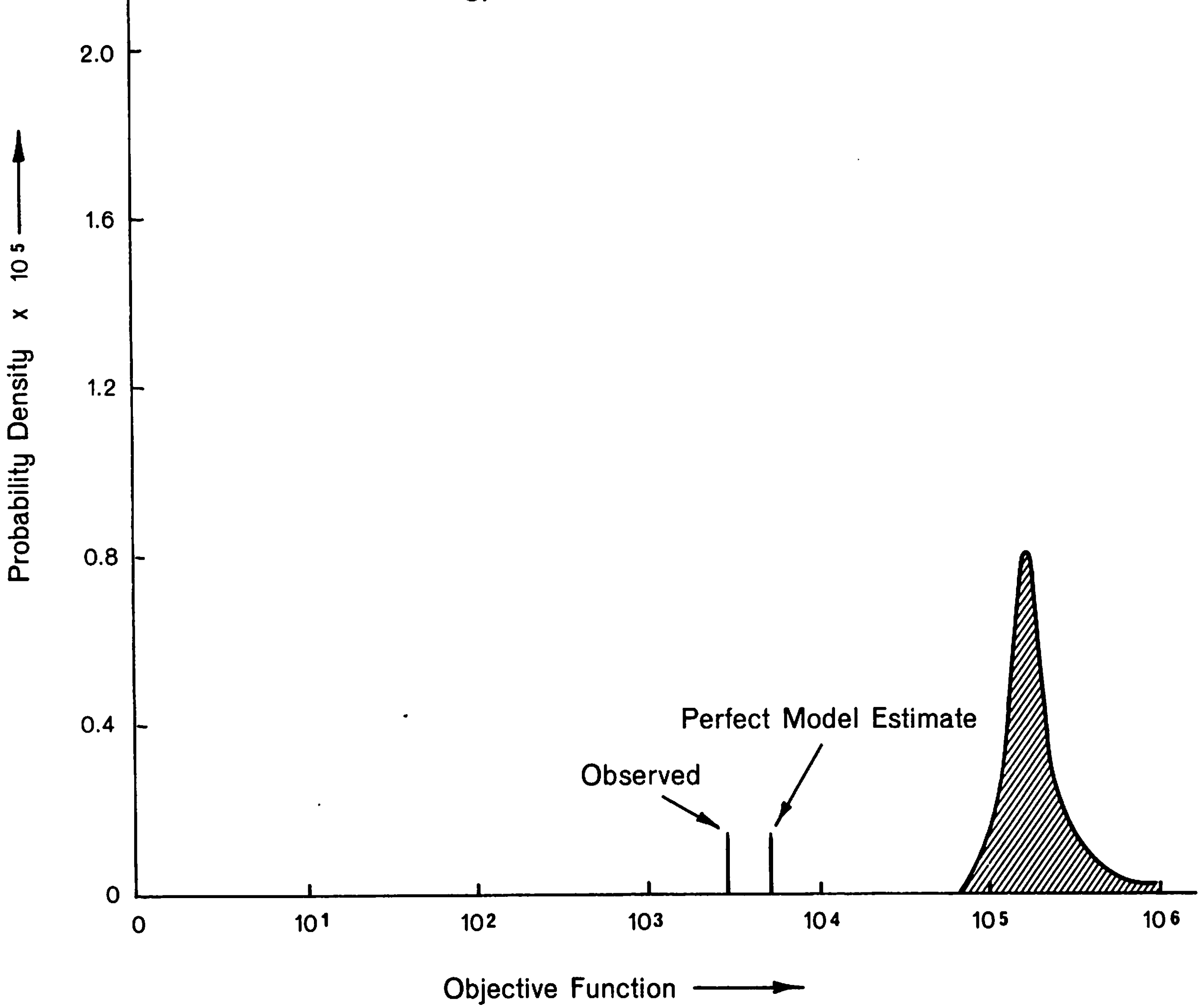
The first model assumes a constant participation rate, so that the number of users is a constant proportion $\underline{a}$ of the total population in each Enumeration Area. The goodness of fit of the model is relatively sensitive to this parameter; it was calibrated at .0115 with a sensitivity of 9.2×10^{-4} (Table 1).

In Models 2 and 3 $\underline{a}$ was replaced by a participation rate a_1 for each of eight age groups. In both cases the most important group was the 5 - 15 although the middle-age groups, 35-45 and 45-55, show relatively high sensitivity because their presence is a good indicator that an Enumeration Area also contains large numbers in the 5 - 15 age group. The other groups have relatively low and unimportant participation rates.

The distance power $\underline{b}$ shows the highest sensitivity in each model, and very little change in value. A figure of 1.84 can be interpreted as

Figure 4

Observed and Hypothesized Values of the Objective Function.



indicating that if two sites are equal in every respect, with one twice as far from a group of users as the other, the probability of visiting the closer one would be $2^{1.84}$ or 3.58 times the probability of the further one.

The fitted attractions are consistent over the three models. The lowest values correspond to those sites whose hinterlands appear largely distance-determined, while the highest values provide an incentive to bypass closer pools and thus correspond to the more diffuse areas. The values might be correlated with a variety of attributes of each facility to determine the factors responsible for varying attraction.

The final parameter δ appears in Model 3 as the stay-at-home alternative. The fitted value had a relatively low sensitivity, and the model gave little improvement in the objective function over Model 2, suggesting that the additional parameter has little importance. The numbers of non-users predicted by Model 3 were small, in few cases exceeding 10% of the users in an Enumeration Area. It appears that the number of users is largely independent of the supply of this particular recreational activity, and that very few non-participants can be regarded as potential users of an increased supply of alternatives.

7. The Location/Allocation Problem

The problem of optimum pool location was conceptualized as follows. There are eleven existing locations and two new ones. Given a set of 13 locations, individuals will make choices which result in aggregate flows in accordance with the interaction models analyzed in the previous sections. Thus allocation follows once locations are known.

The two new locations were chosen to minimize the total distance travelled by the users in the system,

$$\text{Min} \sum_i \sum_j I_{ij} D_{ij}$$

where the pattern of users, I_{ij}, is itself a function of the locations chosen. Trivial solutions will sometimes result from this criterion, since a site can minimize the distance travelled by its users by moving so far away as to have no users. But the problem does not arise with these interaction models because the total flow from each origin is constrained to a finite level.

Most location/allocation literature has been concerned with problems in which both location and allocation are taken to be controllable; there is relatively little work on cases where users allocate themselves by an uncontrolled spatial decision process. Holmes, Williams and Brown (1972) allowed demand to vary with distance in finding the optimum locations for day care centres, but all demand was assumed assigned to the nearest available facility. Abernathy and Hershey (1971) allowed users to choose between facilities, but modelled the decision on distance alone, without allowing facilities to have varying attraction.

The problem was solved by a modification of the alternating Cooper (1963) heuristic. The solution process begins with the eleven existing sites, together with intuitively chosen starting locations for the two new ones. Allocations are made according to the interaction model, and the two new sites then moved to optimal locations for their own allocated demand. The eleven existing sites are fixed throughout the analysis. A new allocation follows, then a relocation, until no further change results. The algorithm is heuristic, and one would expect the choice of starting locations to have some influence on the final result.

The data for the procedure consisted of:

(1) A series of origin points, enumeration area centroids, with each area's population by age group.

(2) A set of existing facilities with x,y locations and attraction values.

(3) A description of the spatial choice process, in this case the calibrated interaction model.

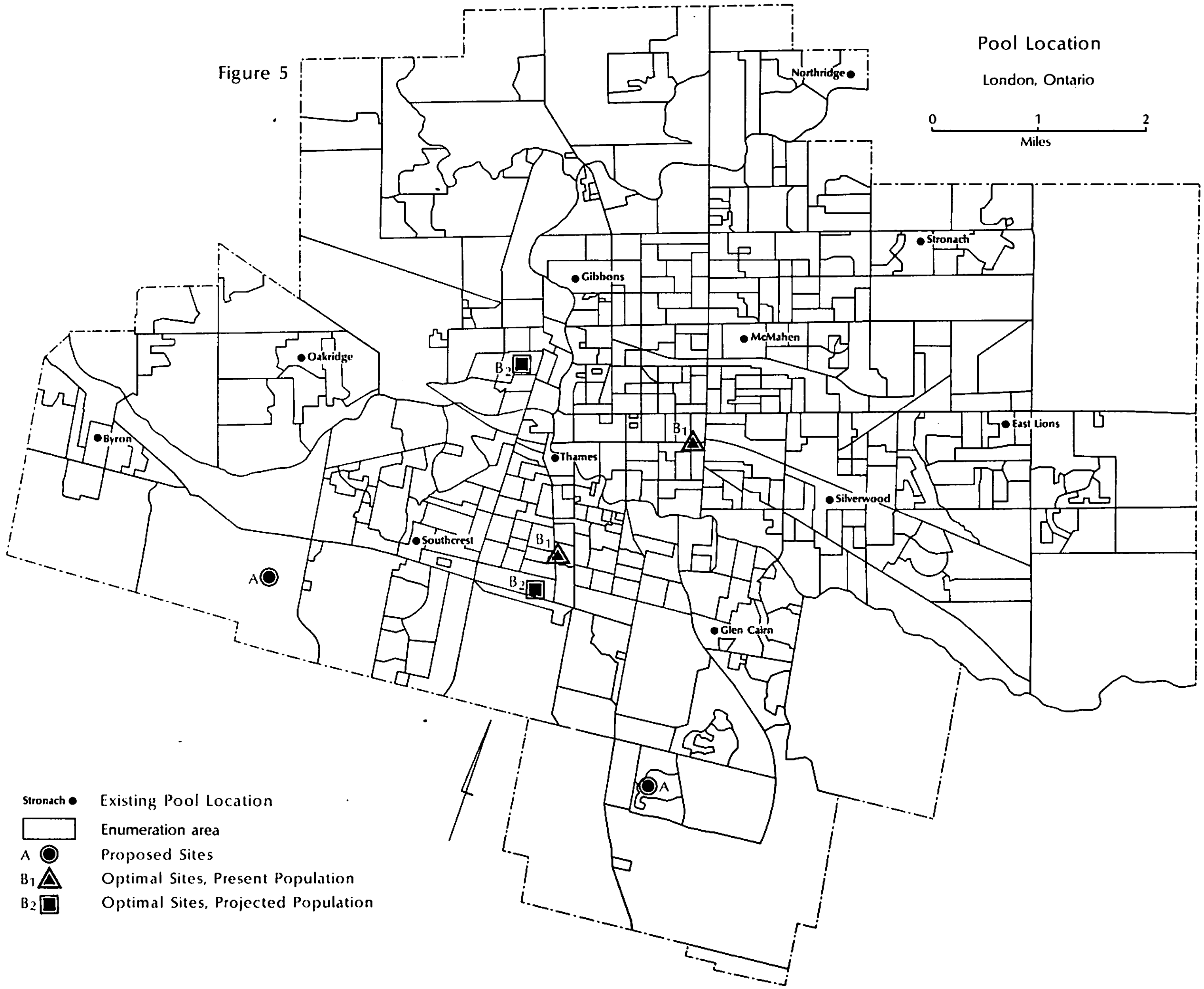
(4) A set of proposed new locations with attraction values set equal to the mean attraction of existing sites.

Two analyses were carried out for the set of facilities. In the first, present population figures were used as a basis from which to compute predicted interactions. The second analysis considered future population growth within the city by using London Planning Board projections for 1990 in each enumeration area. In both cases the proposed locations were used as starting points for the two new sites.

In principle, any of the three interaction models might be used as a basis for allocating demand. However, Models 2 and 3 require a breakdown of population by age, which prevented these models being applied to the 1990 projection. All three models were applied to the analysis of the existing population distribution; the differences were so slight that only the results of Model 1 are presented.

The results for the analysis of existing populations showed a tendency to move the new sites into the central part of the city. The core area was designated as one where a site could be located, and a second site placed in the south central part of the city (Figure 5). These two areas both have high population concentrations and in the case of the core region

Figure 5



Pool Location
London, Ontario
0
1
2
Miles
Northridge
Stronach
Gibbons
McMahen
Oakridge
Byron
Thames
East Lions
Silverwood
Southcrest
Glen Cairn
A
B_1
B_2
Stronach
Existing Pool Location
Enumeration area
A
Proposed Sites
B_1
Optimal Sites, Present Population
B_2
Optimal Sites, Projected Population

lack an established public facility.

In the second run with projected populations, proposed sites were moved both westward and southward from the optimal locations of the first run. One is in the West London planning district which has a projected growth factor of 2.15 while the other is in the Highland planning district with a growth factor of 1.92. In both instances the locations defined by the procedure were closer to the actual planned locations than in the first run.

Table 2 shows the values of the objective function, and of the mean distances travelled to each of the new sites before and after relocation from the proposed positions. Since only two sites are relocated by the analysis, there is only marginal improvement in the objective function; but the contribution to the objective function from the two new sites shows a substantial improvement in both cases.

Table 3 shows the proportions of demand allocated to each site at the optimal solution. The demand at both new sites increased substantially during relocation; at the final iteration both are among the most popular.

The contrast between the proposed, or 'A' locations, and the optimal, or 'B' sites, is best explained from the perspective of the interaction model. The proposed locations quite clearly follow the service area concept, since they appear to be placed such that if a circle of radius 1.5 miles were drawn around each one, it would cover an area of strong current and potential population growth, and overlap little with existing circles. This supposition was checked by solving a modified location/allocation problem. Users were allocated by assignment to the nearest facility, rather than by Model 1, and the objective was changed to the minimization of distance travelled in excess of 1.5 miles in any trip. The resulting

TABLE 2

	Iteration	Total Distance Travelled	Mean Distance Travelled (miles) Per User	
		miles	Site 12	Site 13
Existing Populations	0	6885	2.0	2.0
	20	6697	1.2	1.2
Total users 2,567				
Projected Populations	0	10650	1.8	1.8
	20	10540	1.3	1.3
Total users 3,786				

TABLE 3. Proportion of Demand Allocated to Pool Sites After Relocation

	Site	Existing Populations %	Projected Populations %
1.	Thames	6.7	6.3
2.	Oakridge	5.0	4.3
3.	Glen Cairn	9.3	9.7
4.	Gibbons	8.6	8.2
5.	East Lions	7.0	6.2
6.	Stronach	8.6	8.2
7.	Silverwoods	10.5	9.0
8.	Northridge	5.4	5.7
9.	McMahon	8.1	7.6
10.	Byron	4.7	5.5
11.	Southcrest	8.7	9.8
*12.	Westmount	8.9	9.9
*13.	Westminister	9.1	9.6

*New Sites

locations for the two new centres were close to the proposed sites; the differences can readily be explained by the need to propose sites on available land rather than at the precise geographically optimal locations.

On the other hand, the B locations were determined by allocating users according to a model of the user choice process. The model allows substantial overlap between areas, particularly where there are differences of attraction to outweigh additional trip length. As a result, new sites can have more impact on the distances travelled by users if they are placed in the gaps between existing pools in the high density areas of the city, rather than on the suburban periphery. Projected suburban growth moves the optimal B locations outward, but not as far as the proposed A locations.

The contrast between A and B sites can also be attributed to differences in long-term strategy. Many more than two additional pools are needed to place the entire city under 1.5 miles radius service areas, particularly in the northwest. The proposed locations simply defer additional coverage, whereas the B location process attempts to satisfy the demands of all users in the city immediately. The result is to pull the B locations toward the northwest.

Scott (1971) has discussed the determination of optimal locations against both long and short term strategies. In the short term, or 'myopic' case, the planner would determine the number of facilities to be built in the immediate future, and solve the problem for that number, as in the B solution above. A long-term strategy would determine the number of facilities needed at some distant planning horizon, and their optimum locations. A second analysis would then provide the optimal construction sequence, so that the most needed facilities would be built first, but in locations that would eventually yield the optimal pattern.

8. Summary

Any system of spatially separated supply and demand can be visualized as a series of components. The functioning system observed in the real world is the result of a complex interplay between the behavior of consumers, in choosing between alternative sources of supply, the decisions made by those responsible for the supply locations, and a variety of fixed physical characteristics such as the geographic distribution of the population, the network of available transportation routes, and the availability of land for siting sources of supply.

Public swimming pools supply a service, and are located through the decisions of recreation planners, who must interpret the wishes and objectives of various sections of society in developing a plan, and then in turn explain and justify those decisions. Thus the planner represents one of the three components of the spatial system, locating pools so as to achieve a certain desired pattern of overall spatial interaction of supply and demand. But the eventual pattern can only be predicted when the planned locations are combined with an accurate knowledge of the consumer decision-making process, and of the physical characteristics and constraints. 1.5 mile service radii are inappropriate in a system where consumers frequently travel much further and frequently reject nearby alternatives. Similarly, locations must be planned for those age groups that will use them, and not for gross populations.

The approach to optimal recreation facility location presented in this study has several advantages over traditional location/allocation methods. The allocation of users is controlled not by a desire for optimality but by empirical behavioral principles, and is therefore not a decision variable in the usual location/allocation sense. Once chosen, locations generate their own unique pattern of allocation through the interaction model.

The interaction model is based on assumptions about individual behavior; provided those assumptions are true, the calibration of the model will be general, and independent of the precise geometry of this set of data. Since the value of $\underline{b}$ is determined by the way in which individuals compromise distance with attraction, it is independent of the availability of facilities or their spatial arrangement.

Finally, while location/allocation solutions are the result of optimizing objective criteria, they cannot include all the factors that are important in site selection. They should be regarded as ideal benchmarks, providing a basis for the evaluation of pragmatic and inevitably suboptimal reality.

REFERENCES

Bangs, H. P., and S. Muhler, 1970. "Users of Local Parks," Journal of the American Institute of Planners, Vol. 36, No. 5, pp. 330-334.

Batty, M., and S. Mackie, 1972. "The Calibration of Gravity, Entropy and Related Models of Spatial Interaction," Environment and Planning, Vol. 4, pp. 205-234.

Beaman, Jay, 1973. "Internal Standard for Recreation Analysis," unpublished paper, Parks Canada, Ottawa, pp. 1-14.

Beaman, Jay, and J. B. Leicester, 1970. "Supply and Use of Facilities Theory and Modelling Considerations Applied to Recreation Facilities," unpublished paper, Parks Canada, Ottawa.

Beaman, J., J. L. Knetsch, and H. K. Cheung, 1974. Heteroscedasticity and Weighted Regression: an Application of Generalised Least Squares to Park Use Estimation, Ottawa: Parks Canada, CORD Technical Note 19.

Cesario, F. J., 1974. "More on the Generalised Trip Distribution Model," Journal of Regional Science, Vol. 14, pp. 389-397.

Dee, Norbert, and J. C. Leibman, 1970. "A Statistical Study of Attendance at Urban Playgrounds," Journal of Leisure Research, Vol. 2, pp. 145-159.

Evans, A. W., 1971. "The Calibration of Trip Distribution Models with Exponential or Similar Cost Functions," Transportation Research, Vol. 5, pp. 15-38.

Ewing, G. O., 1974. "Gravity and Linear Regression Models of Spatial Interaction: A Cautionary Note," Economic Geography, Vol. 50, pp. 83-88.

Gans, H., 1969. "Planning for People Not Buildings," Environment and Planning, Vol. 1, pp. 33-46.

Gold, Seymour M., 1972. "Non Use of Neighbourhood Parks," Journal of the American Institute of Planners, Vol. 38, No. 6, pp. 369-378.

Goodchild, M. F., 1975. Fitting the General Spatial Interaction Model to Recreation Trip Data, Ottawa: Parks Canada, CORD Technical Note 35.

Holmes, J., F. B. Williams and L. A. Brown, 1972. "Facility Location Under Maximum Travel Restriction: An Example Using Day Care Facilities," Geographical Analysis, Vol. 4, pp. 258-266.

Luce, R. Duncan, 1959. Individual Choice Behaviour, New York: John Wiley.

Mueller, G. H., and H. E. Echelberger, 1974. "Approaches to Forecasting Recreation Consumption," in Outdoor Recreation Research: Applying the Results, U.S.D.A. Forest Service, General Technical Report NC 9, pp. 43-55.

Porteous, H., 1971. "Design with People -- The Quality of the Urban Environment," Environment and Behaviour, Vol. 3, p. 2.

Powell, M. J. D., 1965. "An Efficient Method for Finding the Minimum of a Function of Several Variables Without Calculating Derivatives," Computer Journal, Vol. 7, pp. 155-162.

Scott, A. J., 1971. "Dynamic Location-Allocation Systems: Some Basic Planning Strategies," Environment and Planning, Vol. 3, pp. 73-82.

Sessoms, Douglas, 1964. "New Bases for Recreation Planning," Journal of the American Institute of Planners, Vol. 30, No. 1, pp. 26-31.

Shivers, Jay and George Hjelte, 1971. Planning Recreational Places, Cranbury, N.J.: Farleigh Dickenson University Press.

Wolfe, R. I., 1964. "Perspectives on Outdoor Recreation, A Bibliographical Survey," Geographical Review, Vol. 54, pp. 203-238.

RESEARCH PROGRAM:

IMPACT OF THE PUBLIC

SECTOR ON LOCAL ECONOMIES

The Department of Economics, University of Western Ontario, has recently mounted a long-term research program on the Impact of the Public Sector on Local Economies. The program publishes Discussion Papers and Research Studies. Copies may be obtained by writing:

Mrs. Jayne Dewar
Secretary
Urban Research Program
Department of Economics
The University of Western Ontario
London, Ontario N6A 5C2
Canada

The following Discussion Papers and Research Studies are currently available:

DISCUSSION PAPERS:

001 P. T. Chinloy, "Hedonic Prices and Age Deterioration in Urban and Suburban Housing" (September 1975).

002 M. W. Frankena, "Alternative Models of Rent Control" (September 1975).

003 J. R. Markusen and D. T. Scheffman, "Ownership Concentration and Market Power in Urban Land Markets" (October 1975).

004 A. J. Robson, "The Effect of Urban Structure on Ambient Pollution" (October 1975).

005 J. R. Markusen and D. T. Scheffman, "The Timing of Residential Land Development: A General Equilibrium Approach" (November 1975).

006 A. J. Robson, "Cost-Benefit Analysis and the Use of Urban Land for Transportation" (December 1975).

007 M. F. Goodchild and P. J. Booth, "Modelling Human Spatial Behavior in Urban Recreation Facility Site Location" (January 1976).

RESEARCH STUDIES:

01 G. W. Davies and P. L. Jackson, "A Model of the Urban Housing and Residential Land Markets" (September 1975).

02 G. P. Schaefer, "The Urban Area Production Function and the Urban Hierarchy: The Case of Saskatchewan" (October 1975).