METHODOLOGICAL PROBLEMS IN THE ESTIMATION AND USE OF ATTRACTION INDICES IN THE PREDICTION OF RECREATIONAL FLOWS

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INTRODUCTION

The massive growth of the industrial society in North America has produced a society with as much leisure time as any other in the world. The majority of workers have two non-working days each week, plus one to two weeks holiday each year.[1] This body of free time combined with an increasing amount of discretional income has created a "demand" for recreational facilities of all types. Within the variety of recreational trips, the day-trip from the large urban areas to provincial and state parks, has become the trip which produces the most pressure on the recreational facilities.[2] In Canada, with the population concentrated in the urban areas,[3] the day-trip to provincial parks forms the majority of recreational trips outside the urban areas. Thus park planners are faced with the problem of producing park systems around the urban areas that will handle the "demand" for day-trips.

The study of systems of parks, by planners, has been accomplished largely by the application of standard socio-economic models, which generate aggregate flows for the systems. The most frequently utilized models have been the gravity and network-analysis model. However, since "the model is to some extent determined by the objectives it is designed to serve, and the objectives are likely to be modified in the light of calculations made with the model"[4] most studies undertaken have

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1 The Canada Year Book, 1970-71 shows the average hours worked per week in Canada in 1969 at 40.04 hrs./week.

2 The Canada Year Book, 1970-71 shows 88.48% of all trips to Manitoba's provincial parks to be day-trips.

3 The Canada Year Book, 1970-71 shows 73.6% of Canada's population in urban areas.

4 Richard Stone, "The Analysis of Economic Systems," in Study Week on: The Econometric Approach to Development Planning, October 7-13, 1963, (Amsterdam: North Holland Publishing Company, 1965), pp. 7-8.

been confined to the more easily studied activities, such as camping and boating, while the more important day-trip has been ignored due to the difficulties inherent in day-trip studies. The problems associated with the study of day-trips are derived both from the character of this type of trip and the character and measurement of the variables used in the models applied.

The day-trip is distinctly characterized, firstly by the short length of stay at the destination and secondly by the numerous activities undertaken, over a wide area, by the recreator. Due to the short length of stay, collection of data is very difficult, while the longer length of stay combined with stricter registration procedures for campers and boaters overcomes this problem in these cases. However, data collection techniques can be improved and the data available for day-trips should be sufficient for the planner in the future. Two variables used in the predictive models produce less easily solved difficulties for the planner. Present methods of isolation of both the capacity and attractiveness indexes for recreational facilities include detailed analyses of the activities undertaken by the recreator. The complexity of activities on day-trips has made the measurement of these two variables very difficult. This fact combined with the previously mentioned data collection problem has caused researchers to shy away from the day-trip study and concentrate on the more easily manageable camping and boating aspects of park use.

Since the day-trip is the most frequent type of trip undertaken by recreators in North America and specifically in the highly urbanized Canadian situation, more research must be aimed at the prediction of day-trip volumes and less emphasis placed on the presently descriptive aspects of such studies. For such predictive research to be undertaken, utilizing the contemporary trip distribution models, the problem of isolation of variables, as attractivity and capacity must be overcome. Two approaches can be followed to this end. Attempts can be made to improve contemporary methods or new approaches for isolating the index can be employed. This thesis offers one such new approach for the isolation of these variables.

CHAPTER I

One of the main objectives of recreational research is the prediction of future use of recreational facilities. In a superficial sense, recreational facility requirements will be the result of "demand" for such outlets by the population. The inutility of this concept of "demand" is demonstrated by the difficulty of operationalizing the definition most frequently used in the field of recreational research; 'demand for recreation is the propensity of a population to participate in a recreational activity at a specific level of reactional supply and cost'. Present knowledge of the habits of the recreator does not allow adequate measurement of demand as defined. In order to produce an operational definition of "demand" the researcher must utilize the observable characteristics of a population. To this end, the majority of researchers define "demand" as known use or participation at recreational sites.[5]

In order to predict future participation, researchers have attempted to apply standard models of social interaction. These models are based on empirical laws of physics and empirical application to recreational research. The models explicitly formulate the relationships amongst variables which either enhance or detract from aggregate flows of recreators. As Carrothers has pointed out:

> . . . the gravity and potential concepts of human interaction were developed originally from analogy to Newtonian physics of matter. The behaviour of molecules, individually is not normally predictable on the basis of mathematical probability. Similarily, while it may not be possible to describe the actions

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5 Demand and participation or use will have identical meaning throughout this thesis.

> and reactions of the individual human in mathematical terms, it is quite conceivable that interactions of groups of people may be described this way. This possibility is suggested by the phenomena, observable in all social sciences . . . that people behave differently in groups than they do as individuals.[6]

Since H. C. Carey introduced the gravity or interaction concept to social science in 1859, in his paper "The Principle of Social Science," the model has been used by several disciplines and in varying forms. Until use of the gravity model by J. Q. Stewart and G. K. Zipf, in separate works, in the 1940's, little formalization of the model was attempted.[7] Both Stewart's and Zipf's formulation followed strict Newtonian principles:

$$Fij = \frac{Pi\ Pj}{Dij^2}$$

where: Fij = the force of interaction between concentrations i and j

Pi = the attractive mass of concentration i

Pj = the attractive mass of concentration j

Dij = the distance between concentrations i and j

This formula was then extended to produce the energy of interaction of a region:

$$Ei = K \sum_{j=1}^{n} \frac{Pi\ Pj}{Dij}$$

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6 Gerald A. P. Carrothers, "An Historical Review of the Gravity and Potential Concepts of Human Interaction," Journal of American Institute of Planners, (Spring, 1956), p. 99.

7 Before the 1940's E. G. Ravenstein ("The Law of Migration") 1885, E. C. Young ("The Movement of Farm Population") 1924, W. J. Reilly ("The Law of Retail Gravitation") and H. S. Bossard ("Residential Propinquity as a Factor in Marriage Selection") 1932, were the only authors to attempt to use the gravity formulation.

where: K = a constant of proportionality, equivalent to the gravitational constant of physics.

This model was then tested on the interaction between pairs of cities using such variables as telephone calls, bus passenger movement and newspaper circulation.

Further experimentation with the model was conducted by several other researchers, including D. O. Price ("Distance and Direction as Vectors of Internal Migration"), J. D. Carroll ("Spatial Interaction and the Urban Metropolitan Description") and F. C. Iklé ("Sociological Relationships of Traffic to Population and Distance"). From these works and the works of T. R. Anderson ("Intermetropolitan Migration: A Comparison of the Hypothesis of Zipf and Stouffer") came the suggestion that the friction of distance was non linear and should be taken to a variable power other than unity. Thus the formulation became:

$$Fij = K \frac{Pi}{Dij^{x}}$$

where: $x = f\ (Pi)$

so that x will vary inversely with some function of the size of population. G. A. P. Carrothers has suggested

> . . . that the evidence may also be interpreted in a somewhat different way: namely that the exponent may be a variable function related inversely to distance itself, rather than to population [since] . . . an extra unit of distance added to a long movement is of less importance than an extra unit added to a short movement.[8]

Thus x from the above formula now becomes:

$$x = f\ (Dij)$$

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8 Carrothers, *op.cit.*, p. 97.

A further modification of the model was produced by J. Q. Stewart and S. C. Dodd in separate papers.[9] This modification assigned 'weights' to the population variables and sought to account for differences in degree of influence which result from different characteristics of populations. The formulation from Stewart's paper is:

$$Fij = K\frac{\mu i\ Pi \cdot \mu j\ Pj}{Dij^{x}}$$

where: μi = the molecular weight of population i

μj = the molecular weight of population j.

A. Voorhees ("A General Theory of Traffic Movement") suggested that these molecular weights should be renamed 'attractive indexes' and that these indexes could be measured in many instances. He produced an empirical study to demonstrate the method using floor area devoted to the sale of apparel as his index while studying movement of shoppers within a metropolitan area.

S. A. Stouffer radically departed from previous works in his paper "Intervening Opportunities: A Theory Relating Mobility and Distance." He suggested that there is no relationship between distance and mobility, but that the number of people going a given distance is directly proportional to the number of opportunities at that distance and is inversely proportional to the number of intervening opportunities.

$$\frac{\Delta Y}{\Delta S} = \frac{a \cdot \Delta X}{x \cdot \Delta S}$$

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9 J. Q. Stewart, "Population Potential in Metropolitan Areas," (unpublished M.C.P. thesis, Massachusetts Institute of Technology, 1949); and S. C. Dodd "The Interactance Hypothesis: A Gravity Model Fitting Physical Masses and Human Groups," American Sociological Review, Vol.15, No. 2, pp. 245-6.

where: x = the intervening opportunities

a = constant

Δ Y = number of persons moving from origin to a circular band of width Δ S

Δ X = number of opportunities within band of width Δ S

However, Stouffer encountered problems of measuring 'opportunities' and his theory has found little acceptance in more recent research.

As F. Lukermann and P. W. Porter have stated,

> the last ten years have seen the gravity model applied to a great variety of social data in the fields of marketing, traffic analysis, city planning, predicitions of demographic trends, economic geography, etc. Two trends are evident in these recent studies: (1) the hypothesis has been applied increasingly to specific problems at large scales (traffic prediction in large cities, for example); and (2) the model has been assumed to be correct and then used to describe quantitatively the effect of political or linguistic boundaries, or the effects of free competition or monopoly on economic activity.[10]

The impact of the gravity formulation has also been felt strongly in the field of recreation. Numerous researchers have applied the model to the problem of the prediction of future demand since the early 1960's.

D. J. Volk used the model to analyze travel to national parks in the United States.[11] To measure the effect of distance, he computed the per capita visits from each state to each park and plotted the results against distance to the park on a log-log scale. Earlier he had collaborated with E. L. Ullman and R. R. Boyce to produce two other

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10 F. Lukerman and P. W. Porter, "Gravity and Potential Models in Economic Geography," Annals of the Association of American Geographers, Vol. 50, No. 4, December 1960, p. 497.

11 D. J. Volk, "Factors Affecting Recreational Use of National Parks," (paper given at Annual Convention of the Association of American Geographers, Columbus, Ohio, 1965).

papers utilizing the model for prediction of attendance at water-oriented parks.[12] Charles C. Crevo working on a smaller scale than Volk studied weekend recreational travel to two parks in Southeastern Connecticut. He varied the distance factor from Volk's and utilized a time-distance measure. This technique had earlier been suggested by D. J. Carroll, T. R. Anderson and Walter Isard in separate papers.[13] Crevo constructed zones around the parks and the ratio of actual to theoretical trips was calculated for each zone. A method similar again to Volk's was used by R. L. Adams to study the effect of distance on the demand for day-use, camping and interior use of Algonquin Park.[14]

A different formulation than Volk, Crevo and Adams had used was produced by L. L. Schulman in 1964.[15]

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[12] D. J. Volk, E. L. Ullman, R. R. Boyce, "The Merimace Basin" St. Louis, 1961; and D. J. Volk and E. L. Ullman, "An Operational Model for Predicting Reservoir Attendance and Benefits: Implications of a Location Approach to Water Recreation," Papers, Michigan Academy of Science, Arts and Letters, XLVII, 1962, pp. 473-84.

[13] D. J. Carroll, "Spatial Interaction and the Urban Metropolitan Description," Papers and Proceedings of Regional Science Association, Vol. I, 1955; Theodore R. Anderson, "Potential Models and Spatial Distribution of Population," Papers and Proceedings of Regional Science Association, Vol. 2, 1956; Walter Isard and Freutel Guy, "Regional and National Product Projections and Their Interrelations," in Long Range Economic Projection, Studies in Income and Wealth, Vol. 16.

[14] Robert L. Adams, "The Demand for Wilderness Recreation in Algonquin Provincial Park" (unpublished M.A. thesis, Clark University, 1966).

[15] L. L. Schulman, "Traffic Generation and Distribution of Weekend Recreational Trips" (unpublished M.Sc. thesis, Purdue University,

$$Tij = \frac{Ti \cdot \frac{Rj}{Dij^{x}}}{\sum_{j=1}^{n} \frac{Rj}{Dij^{x}}}$$

where: Tij = the corrected number of trips from County j to Park i. A correction factor was needed since the model tends to either over or underestimate the total number of trips attracted to a park. The correction factor for Park i, for example, was a ratio of the observed and calculated number of trips to Park i from all residential areas.

Rij = a measure of the number of recreational trips generated from county j.

Ti = the total number of automobile trips attracted to Park i from all residential areas.

Dij = the road distance between county j and Park i.

x = the value of the exponent for Dij

This model, although utilizing the gravity concept, was formulated along probability lines and calculates through ratio measured the expected number of trips. An extension of this method is found in a more recent work by E. B. Wennergren and D. B. Nielsen.[16] The authors attempted to formulate a probabilistic model and technique for projecting data to be used in statistical estimation of recreation demands. The method was designed to enable prediction of demand at unconstructed recreational sites and to eliminate the use of "ex post" estimates to user demand and resource values. The Study used eight cities of origin of boaters in Northern Utah as an empirical example. The formula used is:

$$P_{ik} = \frac{S_k^a \;/\; D_{ik}^b}{\sum_{k=1}^{z} S_k^a \;/\; D_{ik}^b}$$

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16 E. B. Wennergren and D. B. Nielsen, "Probability Estimates of Recreation Demand," Journal of Leisure Research, Vol. II, No. 2, (Spring, 1970), pp. 112-122.

where: P_{ik} = Probability of a boater at a given origin (i) selecting an alternative boating site (k)

S_k = Surface area of the K^{th} boating site

D_{ik} = Distance from the i^{th} origin to the k^{th} boating site (i goes from 1 to n, k goes from 1 to z)

a = A parameter which reflects the effect of surface area of the site on the number of trips to the site

b = A parameter which reflects the effect o distance on the number of trips to the site.

and then to predict the actual trip distribution:

$$Y_{ik} = P_{ik} \cdot Y_i$$

where: Y_{ik} = Expected number of trips per season from the i^{th} origin to the k^{th} site

Y_i = Total number of trips per season taken by all boaters from the i^{th} origin.

The authors point out that

> the predictive ability of the model is closely associated with the exponent values (a and b) which reflect the effect of surface area and travel distance on the number of trips taken. These exponents were set equal to 1.0 in the earlier example, but are likely critical to accurate prediction of visitation rates. At each origin, boaters may place different emphasis on the importance of travel distance and surface area in their selection of boating sites. Computation of the exponential parameters can be made, subject to the following conditions:
> 1. Let (a) and (b) represent the exponents desired for Equation (2).
> 2. Find the values of (a) and (b) such that the coefficient of determination (r^2) for the actual and expected number of trips to a given boating site is maximed.[17]

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17 Wennergren and Nielson, op.cit., pp. 116-117.

The formulation for the computation is:

$$r^2 = 1 - \frac{\sum_{k=1}^{z} (Y_{ik} - \hat{Y}_{ik})^2}{\sum_{k=1}^{z} (Y_{ik} - \hat{Y}_{ik})^2}$$

where: r^2 = coefficient of determination or the proportion of the total variability explained by the model

Y_{ik} = the actual number of trips made to the k^{th} site from the i^{th} origin

Y_{ik} = the average number of trips to the k^{th} site from the i^{th} origin (total trips of the i^{th} origin/total sites visited by the i^{th} origin)

$\hat{Y}_{ik}$ = the predicted number of trips to the k^{th} site from the i^{th} origin

Further explanation demonstrates that this formula

> provides a vehicle for measuring how accurately the model . . . can predict boater trips to various sites. As the predicted and actual number of trips taken from a given origin to the various sites approach equality, the value of r^2 approaches -.0. Thus, the r^2 value represents that proportion of the variation between the observed and predicted visitation rates which is explained by the model.[18]

The authors calculated the "pooled" r^2 for the eight origins as 0.80 and concluded that the method produced significant results.

Another addition to the gravity model in recreation research appears in a dissertation by C. S. Van Doren.[19] He utilizes assumptions first derived from physics but replaces the destination variable with

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18 Wennergren and Nielsen, op.cit., p. 117.

19 Carlton S. Van Doren, "A Recreational Travel Model for Predicting Campers at Michigan State Parks" (unpublished Ph.D. thesis, Michigan State University, 1965).

an "attraction index". This measure of park attraction is calculated from many variables and in this way differs from the S_k variable of Wennergren and Nielsen. His interaction model is:

$$I_{ij} = G \frac{Aj\ Pij}{td_{ij}^{\ b}}$$

where: I_{ij} = the number of campers at Park j from county i

P_i = the population of county i

A_j = attraction index of park j

td_{ij} = the time-distance between park j and county i

G and b = constants

Van Doren tested the validity of the 'attraction index' using camper trips between counties and state parks in Michigan. He found that the index significantly improved the results of the model in comparison to previous studies without the use of this variable. B. Thompson, using a similar model to Van Doren's studied camper trips from ten cities to ten provincial parks in Ontario.[20] He altered Van Doren's formulation by using a less comprehensive attraction index and by adding exponent values to the population and attraction variables. The general form of the equation was as follows:

$$N_{ij} = K \frac{Pi^x\ \ Cj^x}{Dij^z}$$

where: N_{ij} = the number of trips from city i to park j

P_i = population of city i, in 000's

C_j = park capacity (simplified attraction index)

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20 Bryan Thompson, "Recreational Travel: A Review and Pilot Study," Traffic Quarterly, 1967.

Dij = park-city distance in miles

x, y, and z - exponent values.

Although the gravity model has found wide acceptance in the field of recreation research, there are problems associated with its use. Ellis and Van Doren found that

> this formula not only models the complete interaction, but also remains the same regardless of the structure of the particular system, or even the nature of the phenomenon itself. This feature is . . . a great drawback (interaction really is not invariant with structure and nature of the phenomenon).[21]

Thompson states

> the gravity model has been used successfully in the analysis of recreational travel patterns. Its application can be quickly learned and is readily adapted to computer programming. However, there are many problems associated with its use. For example, human behaviour involves more complex sets of forces than argument by analogy to physical law will bring to light . . .. Another problem arises in assigning an exponent of unity to population . . .. Distance poses yet another problem. Measurement is an easy matter, but how well does distance measure the friction effect?[22]

A further difficulty is that the model measures only pair-wise interaction and does not consider the "intervening opportunities" as proposed by Stouffer.

To combat these difficulties several researchers have attempted to formulate models based on different assumptions. The most widely accepted of these models is the 'system analysis' approach designed by

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21 J. B. Ellis and C. S. Van Doren, "A Comparative Evaluation of Gravity and System Theory Models for Statewide Recreational Traffic Flows," Journal of Regional Science, Vol. 6, No. 2, 1966, p. 60.

22 Thompson, op.cit., pp. 532-533.

J. B. Ellis.[23] This model utilizes the theory of linear graphs and through and across variable postulates from electrical network theory. As Ellis and Van Doren state

> the main differences between the gravity and the system theory models can be said to lie in their conceptual formulation. While the gravity model is essentially a formula with component parameters built-in, the system theory is a procedure for constructing a system analog. One can think of an electrical analog, where the origins act like current sources. The current (flow of campers) 'sees' various paths of differing resistance and distributes itself across the network in a minimum-energy fashion, eventually returning to 'ground' via the park components. The flow at each park is thus determined by the relative resistances of all parks, all links, and the relative strengths of all origin sources . . .. It is in this simple way that such effects as 'intervening opportunities' are automatically allowed for.[24]

The formulation of the network model used by Ellis, although later refined,[25] utilizes a branch equation model and is formulated from a semi-Lagrangian graph, in the sense that all the "flow drivers", and all the "edges" corresponding to parks share the "reference point" as a common node. Thus, all of the "flow drivers" can be classified as "chords" of some "tree" and the "edges" corresponding to parks as "branch elements". Using Ellis' notation the formulation is as follows:

$$G \begin{bmatrix} x_p \\ \hline x_{hb} \end{bmatrix} = FY_o = Y$$

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23 J. B. Ellis, "Analysis of Socio-Economic Systems by Physical Systems Techniques" (unpublished Ph.D. thesis, Michigan State University, 1965).

24 Ellis and Van Doren, op.cit., pp. 60-61.

25 J. B. Ellis, Outdoor Recreation Planning in Michigan by a Systems Analysis Approach, Part I, A Manual for "Program Recsys," Michigan Department of Conservation, Technical Report No. 1, May, 1966.

where: G is a matrix n x n with entries:

$$G_{ij} = Ai + \sum_{i=1}^{n} \delta_{ji}^{2} \; Gi \qquad j = 1 \text{ to the number of parks}$$

$$G_{jj} = \sum_{i=1}^{n} \delta_{ji}^{2} \; Gi \qquad j = \text{number of parks to } n$$

and δ_{ji} = 1 if element i is in cutset j and has positive orientation.

δ_{ji} = -1 if element i is in cutset j and has negative orientation.

δ_{ji} = 0 otherwise

x_p = a vector of park across variables of size equal to the number of parks

x_{hb} = a vector of branch highway link across variables of size (n = number of parks)

F = a matrix of size n x (number of origins) with entries:

f_{ij} = 1 if origin area j is in cutset i

f_{ij} = 0 otherwise

Y_o = a vector of known origin through variables of size equal to the number of origins

Y = a vector the product of F and Y_o

A_j = attraction index of the park j

To solve:

If G^{-1} is partitioned in the form

$$G^{-1} = \left[\frac{GI\ 1}{GI\ 2} \right]$$

the park across variables are given by:

$$X_p = [GI\ 1]\ Y$$

the park through variables are given by:

$$X_p = A \circ p + A\,[GI\;1]\,Y$$

where: A = a diagonal matrix of park attraction indexes.[26]

Ellis suggests that, although this model is more complex mathematically than the gravity formulation, the inherent advantage of separate modelling of the parameters of each component produces more accurate and realistic result. Additionally, once the model's basic framework has been formed it becomes easier and faster to use with regard to computer time and preparation time. Beyond the actual predictions of user flows, Ellis claims that the model produces as a secondary result, the actual "pressure" of demand or the propensity of the population to recreate, and from these results can be developed socio-economic components for each origin.

> In essence, then, while gravity modelling assumes the interaction form, system theory modelling assumes elemental component forms and computes the interaction which logically results.[27]

Each of the models employed in recreation research in some way attempts to produce an analogy to the real world. However, the real world is complex and the simplistic nature of the models produces degrees of error in relation to the simplicity of the models. Researchers employ three main procedures to reduce this degree of error:

1) improvement of methods of data collection and tabulation

2) development of improved measurement techniques for variables presently in use

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26 For a more practical explanation of the systems model refer to Appendix A.

27 Ellis and Van Doren, *op.cit.*, p. 61.

3) identification, measurement and addition of new variables. The first two methods involve improving processes already in use and proven to be beneficial to the modelling procedure. Due to this relationship to proven entities these methods are usually successful in reducing error. The third approach, identification, measurement and addition of new variables, involves new ideas and therefore is the most difficult approach.

In order to improve the prediction of recreational demand, a new variable, attraction index of recreation facilities, has been identified and added to the more recent models in the field. This variable was identified by a dual process. Firstly, the realization that no two recreational facilities are alike with regards to the supply of natural and man-made resources and these differences must produce a differing effect on the flow of the recreational populations to these outlets. Secondly, similar variables have been utilized in other fields with respect to the same types of models now being applied to recreational research, specifically the gravity formulation. J. Q. Stewart introduced the concept of 'modifying weights' applied to the population masses in the gravity model[28] and A. M. Voorhees utilized the term 'attractive index' to denote a variable reflecting the drawing power of shopping centres.[29] As in Voorhees' work, the attraction index now used by recreation researchers replaces the P_j or population mass of the trip destination in the models.

Although the identification procedure for this variable is not

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28 Stewart, op.cit.

29 Alan M. Voorhees, "A General Theory of Traffic Movement," the 1955 Past President's Award Paper, Institute of Traffic Engineers, New Haven Connecticut.

unique to the field of recreational research, the uniqueness of the recreational facility ensures the uniqueness of the measurement process. There is no other trip destination, in any other field, which involves the complexity of measurement as does a recreational facility. The large variety of natural and man-made resources and the activities undertaken at such a site produces an enormous conglomeration of variables within this one variable, attraction index. Several researchers have utilized the attraction index in models but few have attempted a comprehensive measurement process. In order to reduce the difficulty of measurement, most researchers have reduced the number of variables in the make-up of the index to a minimum. In most cases this method involves only the use of a single variable, more often than not a capacity measure of the site.[30] When researchers study only participation in one activity for which capacity is easily recognizable, then the index is often adequate.

The work produced by C. S. Van Doren[31] is probably the most comprehensive attempt at the isolation of an attraction index, which has utility for all sites and activities. Van Doren worked from the premise, that since all recreational facilities differed in resource base potential, an attraction index could be calculated by the measurement of this base plus the application of user preferences to the results. To this end, he produced a study of Michigan state parks and isolated an attraction index for camping at each park.

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30 Wennergren and Nielsen, op.cit.; and Thompson, op.cit.

31 C. S. Van Doren, op.cit.

The initial step of the method involved the choice of seventy-two natural, cultural, facility and service variables for each site plus activity variables obtained from the Outdoor Recreation Resources Review Commission studies of the United States. Principal axis factor analysis was used to reduce this massive number of variables to a more manageable unit. Prior to this analysis, each variable was scaled numerically by a subjective 1, 2, 3, 4 . . . n method, so as to reflect the different attractive power of the properties of the variable.[32] The number of variables was later reduced to fifty-five. These were expected to collapse into three main factors:

1) Natural environment

2) Outdoor activities and related facilities and services

3) Facilities and services not related to (2)

However, it was found that the natural resource variables did not separate into one factor but were distributed amongst all factors. To combat this, the activity variables were removed from the analysis and were loaded separately. The number was now reduced to forty-one and the analysis was repeated. The variables collapsed into four main factors:

1) relationship to inland lakes

2) natural resources

3) camping amenities

4) relationship to the Great Lakes

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32 An example of this scalling is as follows:

Vegetation:	Barren	1
	Deciduous	2
	mixed Deciduous + Evergreen	3
	Evergreen	4

To calculate the index the following weighing method was used to alter the factor loadings:

$$W = \frac{r}{1 - r^2}$$

where: W = the factor loading weight

r = the factor loading for each variable

These four scores, plus values calculated for each activity at each park were summed and divided by five to produce an attraction index for each park. These indexes were then standardized around a mean of one hundred with a standard deviation of fifty. The criterion used to choose the best of several analyses was the total variance explained, with the final four factor solution explaining fifty-six percent of the variance.

The indexes were then tested for utility by applying them in the gravity model formulation and use predictions were obtained for each park for a known year. These results were superior to the model without the index. However, Van Doren concluded that the small improvement did not warrant the long and expensive method to obtain the indices. A revision was undertaken to improve the results. A capacity value, Cap, for each park, was used as a weighting factor:

$$Cap = \frac{C}{\bar{C}}$$

where: C = the number of campsites in each park

$\bar{C}$ = the average number of campsites in a park for the state.

The use of this weighting factor produced significantly improved results from the model to warrant use of the index.

Van Doren's method has found acceptance by other researchers, notably J. B. Ellis who utilized this method in a study prepared for the government of Michigan[33] in conjunction with his network analysis model. The influence of Van Doren's work is also apparent in a report prepared by the government of Ontario. The report states:

> . . . the supply of natural resources and facilities is modified by their attractive qualities. In general, it can be said that an individual, given two equidistant parks, will choose the more attractive park. This concept of recreational attraction can be thought of as a quantitative measure of those qualities of an environment that induce pleasure and/or satisfaction in its recreational users. By examining the quantity, quality, cost and variety of the supply of resources and facilities in each zone of recreational opportunity, the model will calculate the relative attractiveness of each zone for all recreation activities.[34]

On the surface, the method of calculating attraction indexes for recreational facilities, developed by Van Doren, seems attractive to the researcher since it takes into account what appear to be all the variables related to attraction. However, a more careful appraisal reveals important drawbacks associated with the method. As with many variables utilized in models by social scientists, the attraction index of recreational facilities is dependent upon the individual's perception-decision process in making up the aggregate flow pattern. The choice of these variables is frequently accomplished by endeavouring to duplicate this individual perception-decision process of the recreator, at least to the extent that this process is understood by contemporary social science. Van Doren attempts to reflect this perception-decision process in order to compile the attraction index. The assumption that this process can be logically

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33 Ellis, op.cit.

34 Ontario Department of Tourism and Information, Tourism and Outdoor Recreation Plan Committee, Progress Report: Tourism and Outdoor Recreation Plan Study: Executive Summary and Technical Summary, (Toronto, June 1970), p. 13.

identified, by a subjective choice of those variables deemed to comprise the attraction index, reduces the value of this method. The attraction index is a value assigned to a recreational facility to denote the effect of that facility on the flow of recreators within the system. *A priori* choices of the properties of this index, as used by Van Doren, are not a logical approach to the isolation of the index, especially when there is no evidence that the variables chosen do in fact enter into the perception-decision process of the recreator in the selection of a facility.

This method also assumes that the researcher is able to identify all variables of which the attraction index is formed. The absence of one or more important variables would further reduce the utility of the index. This difficulty is evident in Van Doren's work when he states "an apparent weakness of the index is that it considers only internal (site) characteristics for each park; it does not actually take into account attractions outside the confines of the park (situation)".[35]

Not only is the logic of the approach suspect but the method employed by Van Doren to calculate the index, from the *a priori* decisions, is best pseudo-rigourous. This problem stems from the original scaling of those variables used. Seventy-two variables are identified and measured for this process. This measurement involves numerical scaling by a subjective approach. Forty-one variables are scaled by what Van Doren refers to as a "binary" method. The value assigned is 'zero' if the variable is not present at a facility and 'one' if the variable is

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35 Van Doren, *op.cit.*, p. 106.

present (examples of this type of variable are sand dunes, flush toilets, museums, falls, lifeguard and boat launching ramp). Another eight variables are assigned interval scales according to their properties (an example of this type of scaling is that of the variable vegetation (Barren = 1, Deciduous = 2, Mixed Deciduous and Evergreen = 3, Evergreen = 4). There is no logical method by which a researcher is able to decide whether an individual recreator would rank the properties of these variables in such a manner and therefore the interval scales applied are meaningless.

This application of judgement to the scaling also presents the possibility of operator variance as a secondary problem since the results of the various analyses depend on the judgement used for the original scaling of the variables. When first using this method, on the same set of data as Van Doren, J. B. Ellis noted that his results were different than Van Doren's and attributed this difference to difficulty with the original scaling of the variables.

The major drawback, however, appears in the actual mathematical use of the principal axis factor analysis. Factor analysis involves the reduction of a large number of variables to a small number of principal factors and to accomplish this reduction, a matrix of correlation coefficients between each pair of variables is used. Correlation is a statistical technique which can only be applied to interval data. Yet Van Doren, in his final model, uses twenty-two of forty-one variables which are nominally scaled by his "binary" method. Therefore his results are doubtful mathematically and no logical conclusions can be drawn from them.

The attractiveness index for recreational facilities is definitely

SCHEMATIC DIAGRAM OF A SIMPLE RECREATIONAL SYSTEM

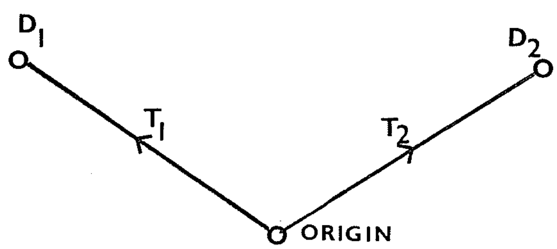

FIG. I

a valid concept upon which the flow of recreators is dependent. However, although the variable has been identified, the method of measurement or isolation used to this point has not been sufficiently accurate to produce an index which can be utilized with a small degree of error. The problem of measurement lies specifically in the inability of researchers in the field to understand the perception-decision process of the individual recreator.

Since it is unlikely that this process will be sufficiently understood for quite some time, a new approach for isolating the attraction index is needed. Instead of attempting to understand the perception-decision process, the result of this process, the observable behaviour of the total population of recreators, should be considered. This behaviour would demonstrate the effects of the perception-decision process on the total flow of recreators within the system. These observable characteristics of a recreational system and of the perception-decision process that could be used to isolate an attractiveness index of recreational facility are:

1) the travel times from the origins to the destinations

2) the total participation or use values at each destination

3) the individual participation or use figures at each destination.

Each of these characteristics of a system is available from present data sources for several types of recreational trips, including the day trip.

The behavioural calculation of indices in its simplest form can be understood when one considers a recreational system (Figure 1) composed of a single origin and two destination facilities (D_1, D_2) each T_1 and T_2 travel time from the origin respectively. Given that $T_1 = T_2$, one can conclude that the ratio of attendance from the origin

(P_1, P_2) will indicate the relative attractiveness of D_1 to D_2. Therefore the relative attractiveness of D_1 to D_2 is equal to (P_1/P_2). A similar attractiveness value can be calculated for D_2, (P_2/P_1). This attraction value for each destination in the system reflects the attraction as perceived by the total population of recreators from the origin and therefore is the true attraction index for the destinations. Thus the varying rates, at which the origin population visits the destinations, dictate the attractiveness of each as perceived by the total population of individual recreators.

If one assumes that the collectively perceived attraction does not vary over a period of years, except in the case of major changes or additions to the recreational system, then indices isolated by a behavioural method can be used for predictive purposes. This is not to say that the indexes will maintain an exactly constant ratio but that this ratio will vary very little. Thus an average value over a period of five years would provide a good predictive tool.

A recent paper by Frank J. Cesario utilizes similar assumptions to obtain the relative attractiveness of recreational facilities. An operational definition of attractiveness is suggested:

> "Relative attractiveness of one destination with respect to another to residents of a particular origin is given by the ratio of the expected number of trips made to the first destination and the expected number of trips made to the second destination from that origin, <u>all other things equal</u>".[36]

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36 Frank J. Cesario, "A New Model for Trip Distribution," (a paper presented at the Eighteenth North American Meetings of the Regional Science Association, Ann Arbor, Michigan, November 12-14, 1971), p. 11.

Cesario also assumes that

> "this does not imply that each individual ranks the destinations similarily, that any one person travels exclusively to one particular destination, or even that the same people are always observed making the trips. The only implication is that the residents of origin i can <u>collectively</u> be observed to prefer Destination 1 to Destination 2 in the same ratio."[37]

These assumptions were then expanded into a new trip distribution model. The behavioural index would be system specific since its value is dictated solely by the observable characteristics of the system. Such an index would no longer be just a value indicating the attractive power of a recreational facility but would be a composite factor which explains the flows in a system. Further study would allow not only accurate prediction of flows but also insights into the relative importance of each recreational facility and the importance of those factors which other researchers had attempted to quantify in order to isolate an index. Since the value is generated by the behaviour of recreators in the system, it would be a composite factor incorporating the effect of the situation of the facility, the capacity of the facility and the effects of both travel time and intervening opportunities as presented to the population of recreators. By summing the effect of these four variables in one measure the problems associated with their separate measurement would be removed.

One of the important limitations of trip distribution studies is the selection of a single model from amongst those available for use.

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37 <u>Ibid</u>., p. 10.

The selection of a model is usually based upon the amount of error expected or allowable for prediction. Of those models available the gravity and network analysis models are the most widely used. The intervening opportunities model has found little use due to the difficulty of measuring the "opportunities". This limitation, of model choice, also applies to the problem of isolating a behavioural index since it would be calculated using one such model. If these indices are to be system specific and are to explain the flows within a recreational system the model which is chosen to calculate the indices must be the appropriate model for the system under study. How is the choice, of which model to utilize, made? Since no one model has been demonstrated to be more accurate or more reliable than any other, the choice of which model to use must be made individually by those involved in the research and prediction. The criteria necessary to make this choice are to be found within the system under study. For day-use studies from single metropolitan areas, the gravity model is probably the most appropriate since day-trips involve simple radial movement from one origin. The lack of alternate parallel routes to the destinations suggests that the intricacy of the network analysis approach is not necessary.

However, lack of investigation of the behavioural attraction index in several models could cause one major problem to be overlooked. It is possible that such indices will not only be system specific but also model specific. If this is the case further research into the causal makeup of the indices would be fruitless and other than allowing accurate prediction these indices would prove useless. Since the day-trip is of prime consideration in this study the gravity model is utilized in the empirical example and to allow some investigation of the above problem similar calculations are made with the network analysis model.

The process of isolating the indices has the advantage of being quite simple. Since each variable in the models is known for a series of base years with the exception of the attraction index and capacity values, a composite value for these variables can be obtained as follows:

<u>for the gravity model</u>

$$Pi = \frac{ai\ ci\ Tj}{Ti^{x}} \qquad (1)$$

where: Pi = the attendance at destination i

ai = the attraction index for destination i

ci = the capacity value of destination i

Ti = the travel time to destination i from origin j

Tj = the total attendance at all destinations (i, i+1, i+2, . . ., i+n) from origin j

x = a constant

Therefore the combined attraction and capacity value can be solved for:

$$Ai = \frac{Pi\ Ti^{x}}{Tj} \qquad (2)$$

where: Ai = ai· ci from equation (1)

<u>for the network analysis model</u>

Due to the formulation of the network analysis model the isolation of the Ai is not possible. However, by holding the value of the other variables (Ti, Tj, Pi) constant and substituting varying values for the Ai variables the attraction index can be isolated, by reducing the standard deviation of prediction to zero for the base year by varying the value of the Ai until this is brought about. The process is identical to that used for the gravity model except that the actual formulation for the Ai variable cannot be demonstrated.

This process of isolating an attraction index overcomes the problems associated with other methods used to this time. There is no longer a need to define all the variables relevant to the calculations, as in Van Doren's method since the resulting index contains all the variables inherent in the index without their definition. The index is system specific and explains the total flow of recreators within the system at the same time removing the difficulty of measuring both intervening opportunities and the situation of the facility.

CHAPTER II

The provincial park system serving the Metropolitan Winnipeg area (see Map 1) is used as an empirical example to compare and contrast the attraction indices isolated by using both the gravity and network analysis model and to allow interpretation of the logic of the method in a practical application. The example specifically deals with day-trips from Winnipeg, to indicate that this method can overcome the problems associated with the prediction of attendance at recreational facilities for this type of trip. The Winnipeg situation is extremely suitable to test this method, since the city is well isolated and on a uniformly flat plain. This situation prevents distortion of results by external influences such a proximity to other large population centres and physical barriers.

There has been controversy over the limits of recreational systems serving urban centres from the beginning of research into day-trip activity. How far does the individual recreator travel on a day-trip or how much travel time will the recreator allow before an outer boundary to travel is reached? Several authors have attempted to answer this question. The California Public Outdoor Recreation Plan suggests "an area within approximately 40 miles of the dwelling",[38] while D. W. Rigby found that 89 percent of Edmontonians travelled within a one hundred mile radius of the city of day-trips.[39] G. D. Taylor proposed a one

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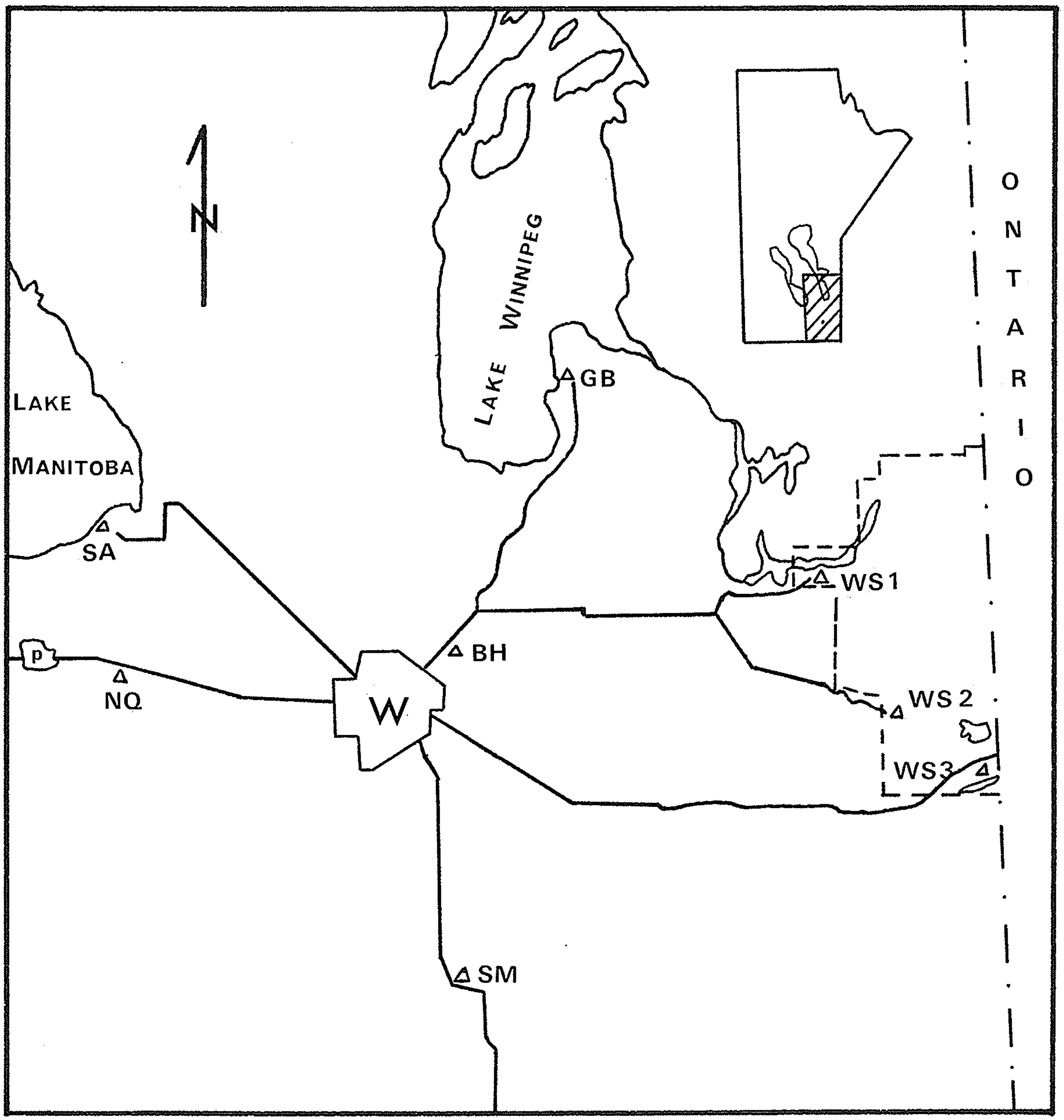
38 California, California Public Outdoor Recreation Plan, Part I, California Public Outdoor Recreation Plan Committee, Sacramento, California, p. 16.

39 D. W. Rigby, Recreational Travel Patterns of Edmontonians; A Sample Study, Unpublished M.A. Thesis, University of Alberta, August 1966, Edmonton, Alberta, p. 95.

STUDY AREA



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MAP1

LEGEND MAP 1

W - Metropolitan Winnipeg

GB - Grand Beach

BH - Birds Hill

SM - St. Malo

SA - St. Ambroise

NQ - Norquay

WS1 - Whiteshell 1 (Seven Sisters entrance)

WS2 - Whiteshell 2 (Rennie entrance)

WS3 - Whitehsell 3 (Falcon Lake and West Hawk Lake entrance)

------- Boundary of Whiteshell Provincial Park

P - Portage la Prairie

hundred and twenty mile limit to day-trips with three distinct zones.[40]

1. inner zone, less than twenty miles
2. intermediate zone, twenty to sixty miles
3. outer zone, sixty to one hundred and twenty miles.

and an O.R.R.R.C. study suggested that "people are unwilling or unable to spend more than two hours in reaching the recreation area, which is somewhere within a maximum range of sixty to one hundred and twenty miles under weekend traffic conditions, from home to site."[41] The differing views on this subject lead to the conclusion that there is little uniformity of travel time for the day-trip in North America and that the conditions of both traffic and road surface surrounding any urban area dictate to a large extent the amount of time allotted to travel. The O.R.R.R.C. study suggests this conclusion with the statement that "the miseries of traffic congestion that confront the family seeking a one day outing have the tendency to limit distance travelled".[42]

Realizing that local conditions dictate the length of time allotted to travel for the day-trip, two criteria were used to establish the outer limits of the system under study. Taking into consideration the traffic conditions around Winnipeg, a maximum two and one quarter hours travel time was used to delimit the area. However, this length of travel

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40 Personal correspondence with G. D. Taylor, former Head of the Research and Planning Branch, Department of Tourism, Recreation and Cultural Affairs, Province of Manitoba.

41 Outdoor Recreation Resources Review Commission, The Future of Outdoor Recreation in Metropolitan Regions of the United States, Report No. 21, 1962, p. 13.

42 Ibid., p. 13.

time allowed two recreation facilities to be reached that had exceedingly low day-trip volumes from Winnipeg.[43] Therefore a second criterium was applied. Only those recreational facilities were included in the system that had a day-trip volume from Winnipeg of over 5000 user units.[44] Map 1 shows the recreational system considered, the relative locations of the eight destinations to Winnipeg and the transportation routes to each.[45]

Two data sets were obtained from the system, the travel times from Winnipeg to the eight destinations and the day-trip volumes from Winnipeg to each of the destinations for 1969. Differing sets of data on travel times were needed for the gravity and network analysis techniques, since the latter requires individual parameters for each link in the road system, while the former utilizes a lump sum of these parameters. Road distances were taken from a Manitoba Department of Highways map and average road speeds were estimated for each type of surface and road (see Table II-1). From this data travel times were calculated for the gravity model. Similarily, travel times were calculated for the network analysis formulation, (see Table II-2). However, the road system was broken down into ten different sections in order to model the necessary

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43 The two facilities not included were Patricia Beach and Spruce Woods Provincial Parks.

44 A user unit is defined as an entry for one day or less into the facility by one individual.

45 Since the Whiteshell Provincial Park is so large compared to the other destinations and has three distinct entrances to three distinct areas of the park, this park was split into three destinations; Whiteshell 1, with entry at Seven Sisters, Whiteshell 2, with entry at Rennie, and Whiteshell 3, with entry at Falcon and West Hawk Lakes.

TABLE II-1

TRAVEL TIMES FOR THE GRAVITY MODEL

PARK	TRAVEL TIME (hrs)*
Grand Beach	1.336
Birds Hill	0.617
St. Malo	1.222
St. Ambroise	1.543
Norquay	1.023
Whiteshell 1	1.742
Whiteshell 2	2.111
Whiteshell 3	1.826

* One half hour travel time was added to each value to account for travel within Winnipeg.

TABLE II-2

TRAVEL TIMES FOR THE NETWORK ANALYSIS MODEL

PARK	LINKS (Fig. 2)	TRAVEL TIME PER LINK (hrs)*
Grand Beach	17,13,10	0.617,0.083,0.636
Birds Hill	17	0.617
St. Malo	9	1.222
St. Ambroise	15	1.543
Norquay	16	1.023
Whiteshell 1	17,13,12,11	0.617,0.083,0.664,0.378
Whiteshell 2	17,13,12,18	0.617,0.083,0.664,0.747
Whiteshell 3	14	1.826

* One half hour travel time was added to links 9,14, 15,16,17 to account for travel within Winnipeg.

SCHEMATIC DIAGRAM FOR THE NETWORK ANALYSIS MODEL

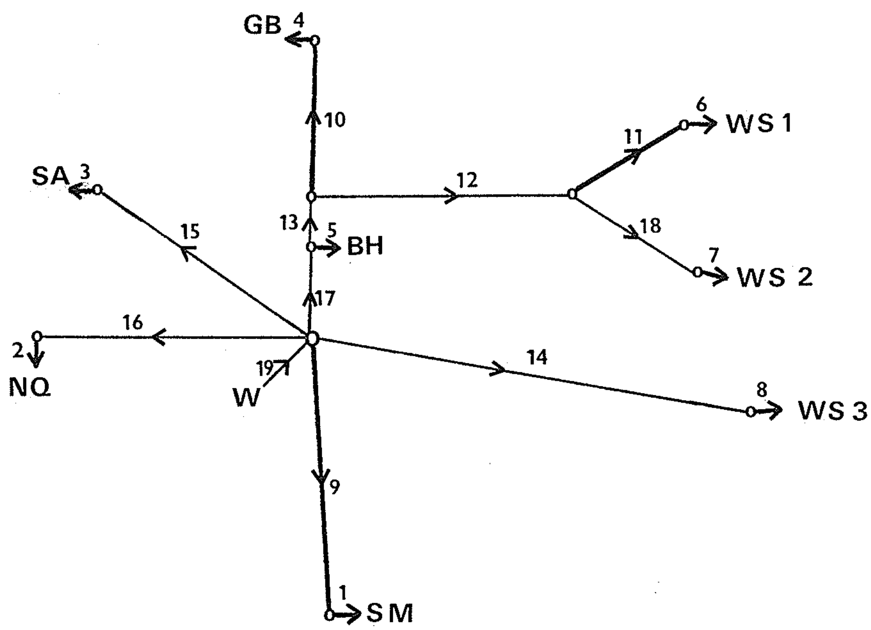

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FIG. 2

LEGEND FIGURE 2

W - Metropolitan Winnipeg (flow input)

GB - Grand Beach

BH - Birds Hill

SM - St. Malo

SA - St. Ambroise

NQ - Norquay

WS1 - Whiteshell 1 (Seven Sisters entrance)

WS2 - Whiteshell 2 (Rennie entrance)

WS3 - Whiteshell 3 (Falcon Lake and West Hawk Lake entrance)

Numbers identify links as they appear in the cutset equations.

Arrows indicate direction of flow in links

Thick lines identify branches

Thin lines identify chords

individual parameters. Figure 2 shows a schematic diagram of the resulting network graph and the numbered road links.

The second data set, day-trip volumes from Winnipeg to each destination, is similar for both models. Since this data is not available in Manitoba the following method was used to estimate the attendances. Total traffic volumes for 1969 were obtained from Park Statistics, 1970.[46] These values were multiplied by the percentage day-trips from Winnipeg, obtained from the Canadian Outdoor Recreation Demand Study samples and then multiplied by the average party size at each park, as estimated by the Manitoba Department of Tourism and Recreation (see Table II-3).

A third data set, unique to the network analysis formulation, was necessary prior to use of the model. The cutset equations (see Appendix A), that indicate the flows through the system, must be formulated for the network graph in Figure 2. These equations are shown in Table II-4.

Prior to calculation with either model, since calibration must be undertaken before the attraction indices are computed, a decision had to be made regarding the exponent of the distance decay function (eg. T^x for the gravity model). Original use of the models, with all variables measured, involved calibration of this exponent to produce as accurate a result as possible. However, this method involves a model which cannot be calibrated prior to use. Several empirical studies have been conducted in an attempt to indicate specific exponents for differing types of trips, yet no concurrence has been reached by researchers.

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46 Manitoba, Park Statistics, 1970, Department of Tourism, Recreation and Cultural Affairs, Research and Planning Branch, January 1971, Winnipeg, Manitoba.

TABLE II-3

ESTIMATED DAY-TRIP ATTENDANCE, 1969

PARK	DAY-TRIP TRAFFIC VOLUMES	PERCENTAGE WINNIPEG DAY-TRIPS	AVERAGE PARTY SIZE	ESTIMATED ATTENDANCE
Grand Beach	70,691	89.04	3.5	220,203
Birds Hill	82,436	90.000	3.5	259,673
St. Malo	41,765	57.39	3.5	83,891
St. Ambroise	5,712	68.91	3.5	13,776
Norquay	7,256	32.91	3.5	8,358
Whiteshell 1	58,887	33.18	3.2	62,524
Whiteshell 2	19,250	33.18	3.2	20,438
Whiteshell 3	154,773	33.18	3.2	164,332
			TOTAL	833,195

TABLE II-4

CUTSET EQUATIONS FOR THE NETWORK ANALYSIS MODEL

BRANCHES	CHORDS	ORIGIN LINK
1*	14,15,16,17	19
2*	-16	-
3*	-15	-
4*	12,-13	-
5*	13,-17	-
6*	-12,18	-
7*	-18	-
8*	-14	-
9	14,15,16,17	19
10	12,-13	-
11	-12,18	-

* Destination branches or park through links

There are arguments both for changing the exponent from unity and for restricting the exponent to unity. E. J. Taaffe, found that "there seemed to be distance effects only within rather restricted inner zones. Beyond these zones there seemed to be a sort of plateau of interaction as regards distance effects."[47] However, W. Warntz suggests "space and time are to be recognized not just as cost incurring external frictions, but rather as dimensions of the economic system and hence to be treated isomorphically in the rigid pattern of mathematical physics".[48] J. Q. Stewart stated that "in many physical situations alternation of the power [ie., the exponent of one] would be a serious matter, not one merely of the choice of an adjustable parameter,"[49] while F. Lukermann and P. W. Porter feel that "certain ubiquitous sociological phenomena may be best described by a gravity model using one as the exponent of distance".[50] Finally Walter Isard confuses the issue when he states "Hammer and Ikle in their studies of telephone calls and airline trips find confidence limits of 1.3 - 1.8 for the exponent of

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[47] Taafe, E. J., "Regional Employment and Population Forecasts via Relative Income Potential Models," Papers and Proceedings of the Regional Science Association, Vol. 5, 1959, p. 49.

[48] W. Warntz, "Geography of Prices and Spatial Interaction," Papers and Proceedings of the Regional Science Association, Vol. 3, 1957, p. 128.

[49] J. Q. Stewart, "Population Projection by Means of Income Potential Models," Papers and Proceedings of the Regional Science Association, Vol. 4, 1958, p. 153.

[50] F. Lukermann and P. W. Parker, "Gravity and Potential Models in Economic Geography," Annals of the American Association of Geographers, Vol. 50, No. 4, Dec. 1960, p. 498.

TABLE II-5

ATTRACTION INDICES FOR 1969

PARK	GRAVITY MODEL		NETWORK ANALYSIS MODEL		GRAVITY FORMULATION	
	EXPONENT 1.0	EXPONENT 1.5	EXPONENT 1.0	EXPONENT 1.5	EXPONENT 1.0	EXPONENT 1.5
Grand Beach	0.35308	0.81611	3.19030	2.56257	11.39343	3.40317
Birds Hill	0.19229	0.30199	1.10880	1.26839	1.69687	0.93107
St. Malo	0.12303	0.27205	0.17519	0.23046	0.30822	0.28780
St. Ambroise	0.02551	0.06337	0.02460	0.03056	0.04717	0.03641
Norquay	0.01026	0.02075	0.01460	0.01784	0.02742	0.02109
Whiteshell 1	0.13072	0.34503	0.47907	0.45289	0.30610	0.23963
Whiteshell 2	0.05178	0.15048	0.14738	0.14667	0.07555	0.05972
Whiteshell 3	0.36014	0.97333	0.58397	2.30942	11.91756	401.28070

distance and finally state that their data 'fail to justify either the inverse linear or inverse square law', which previous investigators has suggested for the distance function.'

Although there is considerable evidence suggesting that the exponent of the d_{ij} distance factor variable need not be 1 or 2, depending on the concept employed, there has not been a definitive study of this question; and Stewart and Warntz cogently point to the inconclusiveness of existing studies and question the scientific basis of such studies."[51]

Since there is no conclusive evidence pertaining to the size of the exponent for distance or travel time, a decision was made to utilize an exponent of 1.0 for this study. However, similar calculations were made to utilize an exponent 1.5, solely for comparison. The value of unity was chosen on the assumption that a linear inverse relationship would exist within a small homogeneous system such as that under study. The expansion of the system beyond a two and one quarter hour limit would probably produce a higher exponent but since the day-trip is the consideration, the small size of the system is guaranteed.

Calculation, using an exponent of 1.0 and 1.5, was completed for both models. The results, the attraction indices for each park, are shown in Table II-5. The indices for the network analysis model were obtained by adjusting their values until the model predicted the known attendance figures as accurately as possible. A standard deviation of prediction of zero was not reached as had been hoped, however, each calculation did produce a standard deviation of prediction of no more than

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51 Walter Isard, Methods of Regional Analysis: An Introduction to Regional Science, Cambridge: The M.I.T. Press, 1960, p. 509.

TABLE II-6

CUTSET EQUATIONS FOR THE NETWORK ANALYSIS MODEL: GRAVITY FORMULATION

BRANCHES	CHORDS (Fig. 3)	ORIGIN LINKS
1	10,11,12,13,14,15,16	17
2	-10	-
3	-11	-
4	-12	-
5	-13	-
6	-14	-
7	-15	-
8	-16	-
9	10,11,12,13,14,15,16	17

TABLE II-7

ATTRACTION INDICES FOR 1968-70*

PARK	1968	1969	1970
Grand Beach	0.34660	0.35308	0.40013
Birds Hill	0.16963	0.19229	0.18575
St. Malo	0.09577	0.12303	0.10868
St. Ambroise	0.01704	0.02551	0.02951
Norquay	0.01124	0.01026	0.01979
Whiteshell 1	0.16992	0.13072	0.12723
Whiteshell 2	0.07982	0.05178	0.05238
Whiteshell 3	0.41972	0.36014	0.31802

* An exponent of 1.0 for the travel time and the gravity model were used to obtain these values.

SCHEMATIC DIAGRAM FOR THE NETWORK ANALYSIS MODEL:

GRAVITY FORMULATION

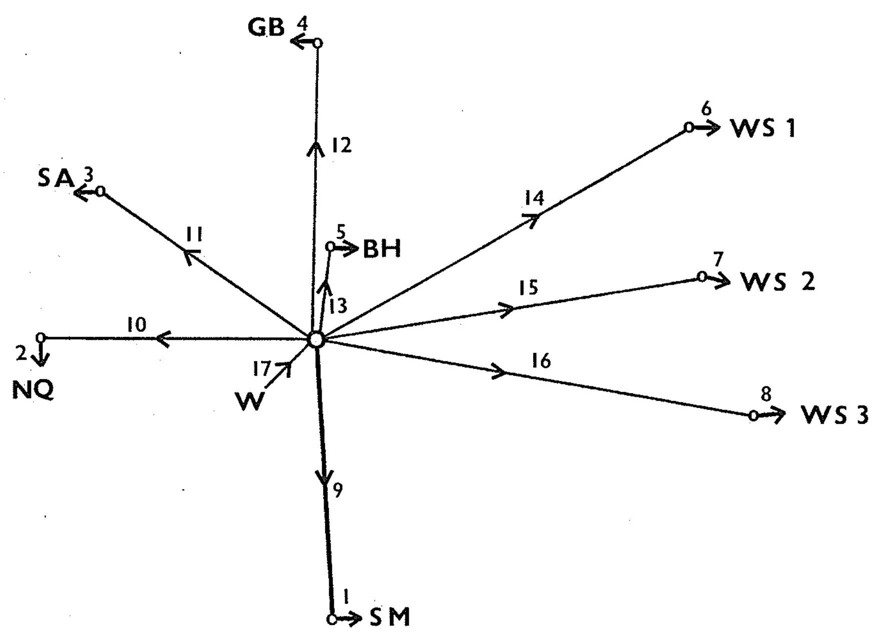

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FIG. 3

LEGEND FIGURE 3

W - Metropolitan Winnipeg (flow input)

GB - Grand Beach

BH - Birds Hill

SM - St. Malo

SA - St. Ambroise

NQ - Norquay

WS1 - Whiteshell 1 (Seven Sisters entrance)

WS2 - Whiteshell 2 (Rennie entrance)

WS3 - Whiteshell 3 (Falcon Lake and West Hawk Lake entrance)

Numbers identify links as they appear in the cutset equations

Arrows indicate direction of flow in links

Thick lines identify branches

Thin lines identify chords

0.1. This value was considered close enough to zero for this study.

A second series of calculations were made with the network analysis model, altered to act in the same way as the gravity model. The purpose of this exercise was to compare these results to the gravity model results. The network graph was altered in such a way as to eliminate travel along one link to two or more destinations and make distinct paths to each destination, thereby reducing the system to a gravity model formulation (see Figure 3). The data input to this model was identical to that of the gravity model, with the exception of the necessary cut-set equations (see Table II-6). The results of these calculations are found in Table II-5.

To allow some comparison of the ratio of the indices for different years and to produce some indication of the similarity of these ratios, the attraction indices were calculated for both 1968 and 1970 in addition to 1969. However, attendance figures for these years, with regard to day-trips are sketchy and most of the values were estimated. Thus some degree of error was expected. Again total traffic volumes were obtained from Park Statistics, 1970 and similar estimates were produced using the same percentage Winnipeg day-trips and average party size as shown in Table II-3. The resultant attraction indices appear in Table II-7.

Restrictions on available data did not allow calculation of indices for other years, than from 1968-70, however, sufficient empirical data is available to allow a reasonable interpretation of the results.

CHAPTER III

Due to lack of accurate data, for day-trip travel from Winnipeg to the recreational system serving the city, it is not possible to interpret the results obtained from the two models in relation to the actual recreational system. However, interpretation of these results is possible with regard to the values produced by the gravity and network analysis model and the relationship of these values to the logic of a behavioural attraction index.

Of primary importance and consideration are the sets of indices[52] produced by both models using an exponent of one for the travel time (see Table III-1). A simple comparison of the values indicates some difference between the results of the two models. Since the data used in both calculations was identical, with the exception of the number of highway links used, the results were expected to be the same. Originally the disparity between the results seemed to be a product of the variation in the number of highway links used. In order to bypass the different number of highway links, the network analysis model was formulated as a gravity model (see Figure 2). In this way the only difference in the data input was eliminated. The results of this calculation is shown in Table III-2. Comparison of these values indicates a wider discrepancy than the previous calculation.

Since the flows through both the gravity model system and the network analysis system (gravity formulation) are identical and the

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52 The indices shown in Table III-1 are the absolute values versus the ratio values drawn in Table II-5. The absolute values were obtained by dividing each ratio index by the ratio index for Grand Beach. Thus the value of 1.00000 for Grand Beach.

TABLE III-1

ABSOLUTE VALUES OF ATTRACTION INDICES FOR 1969

PARK	GRAVITY MODEL	NETWORK ANALYSIS
Grand Beach	1.00000	1.00000
Birds Hill	0.54460	0.34755
St. Malo	0.34844	0.05491
St. Ambroise	0.07224	0.00771
Norquay	0.02905	0.00457
Whiteshell 1	0.37022	0.15016
Whiteshell 2	0.14665	0.04619
Whiteshell 3	1.01999	0.18304

TABLE III-2

ABSOLUTE VALUES OF ATTRACTION INDICES FOR 1969

PARK	GRAVITY MODEL	NETWORK ANALYSIS GRAVITY FORMULATION
Grand Beach	1.00000	1.00000
Birds Hill	0.54460	0.14893
St. Malo	0.34844	0.03495
St. Ambroise	0.07224	0.00414
Norquay	0.02905	0.00240
Whiteshell 1	0.37022	0.02686
Whiteshell 2	0.14665	0.00663
Whiteshell 3	1.01999	1.04600

remaining data inputs are also identical, one could conclude that the differing values of the attraction indices obtained indicates that these behavioural indices are model specific. That is, the size of the attraction index is not based solely on the recreational system and its attributes but is also dependent on the mathematical working of the models involved. If this is the case, these indexes would not indicate the actual attractive power of a recreational facility but would be only a value which conveniently balances the model for a selected base year. Attempts at meaningful comparisons and investigations of the indexes would be pointless.

On the other hand, one could conclude that the indices are not model specific and that the discrepancy between the results is caused by faulty logic in one of the models.

Both the gravity and network models were designed to predict traffic flow and both models operate under similar assumptions. However, the formulations of the models differs greatly. Obviously the difference in formulation between the two models causes similar data inputs to produce different results. The gravity formulation has for several years been considered an adequate model of traffic flow, while the newer network method has not been investigated to any extent as to the logic of its formulation. Since this model does not act logically in a simple gravity formulation there should be some doubt as to its validity.

The network model is based on electrical network theory and the mathematical calculation of flows through these networks. An analogy is drawn between the recreator and the electron and both are considered to act identically within the highway system and the electrical network respectively. On the surface this analogy seems plausible, however, a more careful inspection demonstrates that several factors have been overlooked. In an electrical network the generation of a current causes instantaneous flows throughout the network. These flows are dependent upon the resistance of the links in the network and this in the simplest sense is the only constraint on the flow. However, the resistance (or capacitance as used in the network model) restricts the amount of flow in each link while in a highway system this constraint of capacity of the highway is not taken into account by the recreator. If one considers the flow of recreators along a highway network certain major differences are evident. The response of the individual recreator is not instantaneous within the system. In other words the recreator has no prior knowledge of the traffic condition in the system at the time of departure and has preconceived notions as to the destination. The constraint of resistance (travel time) is the only constraint imposed on the recreator. Unlike the electron, the recreator will not take either an alternate route or change the choice of destination due to overcrowding on the highways, unless the destinations are very closely spaced (not the case in the Winnipeg situation). Therefore the constraints presented in the network model surpass those actually presented to the recreator and probably cause discrepancies in the calculated attraction indices when compared with the more logical gravity model results.

Another cause of the different results produced by the network model can be demonstrated within its formulation. The model utilizes a cutset or connection matrix to solve the flows within a system. This matrix is a series of simultaneous equations as follows:

$$X_{ii} \left[A_i + \sum_{i=1}^{n} T_i \right] \pm \left[n \sum_{j=1}^{n} T_{ij} \right] X_{ij} = F_i \qquad j \neq i$$

where: A_i = attraction index of park i

T_i = conductance value $(\frac{1}{R})$ of the highway links in cutset

T_{ij} = conductance value of the highway links that are included in both cutset i and cutset j

F_i = flow through cutset i, if cutset i contains origin flow generator

X = unknown flow values

The solution vector of these simultaneous equations is then multiplied by a vector of the A_i values. In comparison the gravity model uses the same variables in the following formulation:

$$P_i = \frac{A_i \, T_j}{T_i^{\,x}}$$

where: P_i = unknown flow values for park i (X)

A_i = attraction index of park i (A_i)

T_j = total attendance at all destinations (F_i)

T_i = resistance value for each highway link $(\frac{1}{T})$

X = constant

Although the network model is solved simultaneously the general relationship among the variables for both models is similar, with the exception of the A_i. The addition of the A_i variable to the T variables in the network approach is the specific cause of the discrepancy between the model results. This additive feature causes a variation in the response to the value of the attraction indexes. Thus the results of the two models differ. In order to maintain the analogy to the electrical

TABLE III-3

SENSITIVITY OF THE NETWORK ANALYSIS MODEL

PARK	ATTRACTION INDEX	CHANGE IN THE STANDARD DEVIATION OF PREDICTION 10% CHANGE OF INDEX	100% CHANGE OF INDEX
Grand Beach	3.19030	1.0	5.8
Birds Hill	1.10880	3.2	24.0
Whiteshell 3	0.58397	1.5	10.2
Whiteshell 1	0.47907	2.2	16.8
St. Malo	0.17519	2.7	21.7
Whiteshell 2	0.14738	2.9	24.7
St. Ambroise	0.02460	3.3	31.9
Norquay	0.01460	3.4	33.7

circuit, upon which the model is based, the feature must be included. However, the final multiplication of the equation solutions by the vector of the A_i values is not analagous to the solutions for electrical circuits. The solution, by the cutset method, for the through variables or flows as given in electrical circuit theory is as follows:

$$[G]\ v = i$$

where: $[G]$ = cutset matrix

v = a vector of unknown through variables

i = a vector of known flows from a generator

The final vector multiplication does not appear in electrical circuit theory literature. Thus the validity of the network model is suspect.

A second characteristic of the network model, which also largely contributes to the discrepancy between the results of the two models, is the differing sensitivity to varying sizes of attraction indices. Small changes of indices of low value (eg., St. Ambroise, 0.02460) cause large variations in predicted values, while small alterations of indices of high value (eg., Grand Beach, 3.19030) cause slight variations in predicted results. This property is very apparent when indices reach the size of that found for Whiteshell 3 when using an exponent of 1.5 for travel time (Whiteshell 3, 401.28070). In order to demonstrate this characteristic, each index of the balanced model for 1969 was increased individually by 10% and then by 100%. The effect of this procedure on the standard deviation of prediction, which is used to show the accuracy of the predictions, is given in Table III-3.

With indices of a value larger than 20.0 the change in the standard deviation of prediction is usually less than 0.1%, therefore the exact value of the index cannot be obtained, but only an approximation of its

TABLE III-4

ABSOLUTE VALUE OF ATTRACTION INDICES FOR 1968-70

PARK	1968	1969	1970
Grand Beach	1.00000	1.00000	1.00000
Birds Hill	0.48941	0.54460	0.46422
St. Malo	0.27631	0.34844	0.27161
St. Ambroise	0.04916	0.07224	0.07375
Norquay	0.03242	0.02905	0.04945
Whiteshell 1	0.49024	0.37022	0.31797
Whiteshell 2	0.23029	0.14665	0.13090
Whiteshell 3	1.20807	1.01999	0.79479

TABLE III-5

PERCENTAGE OF CHANGE OF ATTRACTION INDICES 1968-70

PARK	PERCENTAGE CHANGE 1968-1969	PERCENTAGE CHANGE 1969-1970	PERCENTAGE CHANGE 1968-1970
Grand Beach	+ 1.87	+13.33	+15.44
Birds Hill	+13.36	- 3.40	+ 9.50
St. Malo	+28.46	-11.60	+13.48
St. Ambroise	+49.71	+15.68	+73.18
Norquay	- 8.72	+92.88	+76.07
Whiteshell 1	-23.07	- 2.67	-25.12
Whiteshell 2	-35.13	+ 1.67	-34.38
Whiteshell 3	-14.20	-11.70	-24.23
MEAN	21.81	19.12	33.92

value, since the calibrated accuracy of the systems model is sensitive only to a value of 0.1%. Figure 4 allows comparison of the change in the standard deviation of prediction, the size of the attraction index, attendance and travel time for each park. As can be seen from Table III-3 the values for Bird's Hill do not conform to the general trend and this suggests that both attendance and distance play a role in the sensitivity of the model.

Only further research will substantiate that the behavioural attraction index calculated in this manner is solely system specific and not model specific. However, the faults, both logical and mathematical, of the network model indicate that the indices are not model specific in this case. The differences between the indices is not large and the discrepancy can be interpreted as a result of the network formulation.

Of secondary interest are the indices calculated for the years 1968-1970 (see Table II-7). The purpose of these calculations was to attempt to demonstrate that the value of the indexes varied little over a period of several years. Table III-4 gives the absolute values of these indices. Comparison of the values seems to indicate a generally constant index, however, since the values are very small significant differences do not stand out. The percentage increases or decreases from year to year produce a clearer picture of the changes as shown in Table III-5 (the percent changes are taken from ratio indexes).

Obviously in this example there are great fluctuations of the indices over this three year period. Since the data used in this example is poor and both 1968 and 1970 values are estimates, few definite

COMPARISON OF PARK DATA

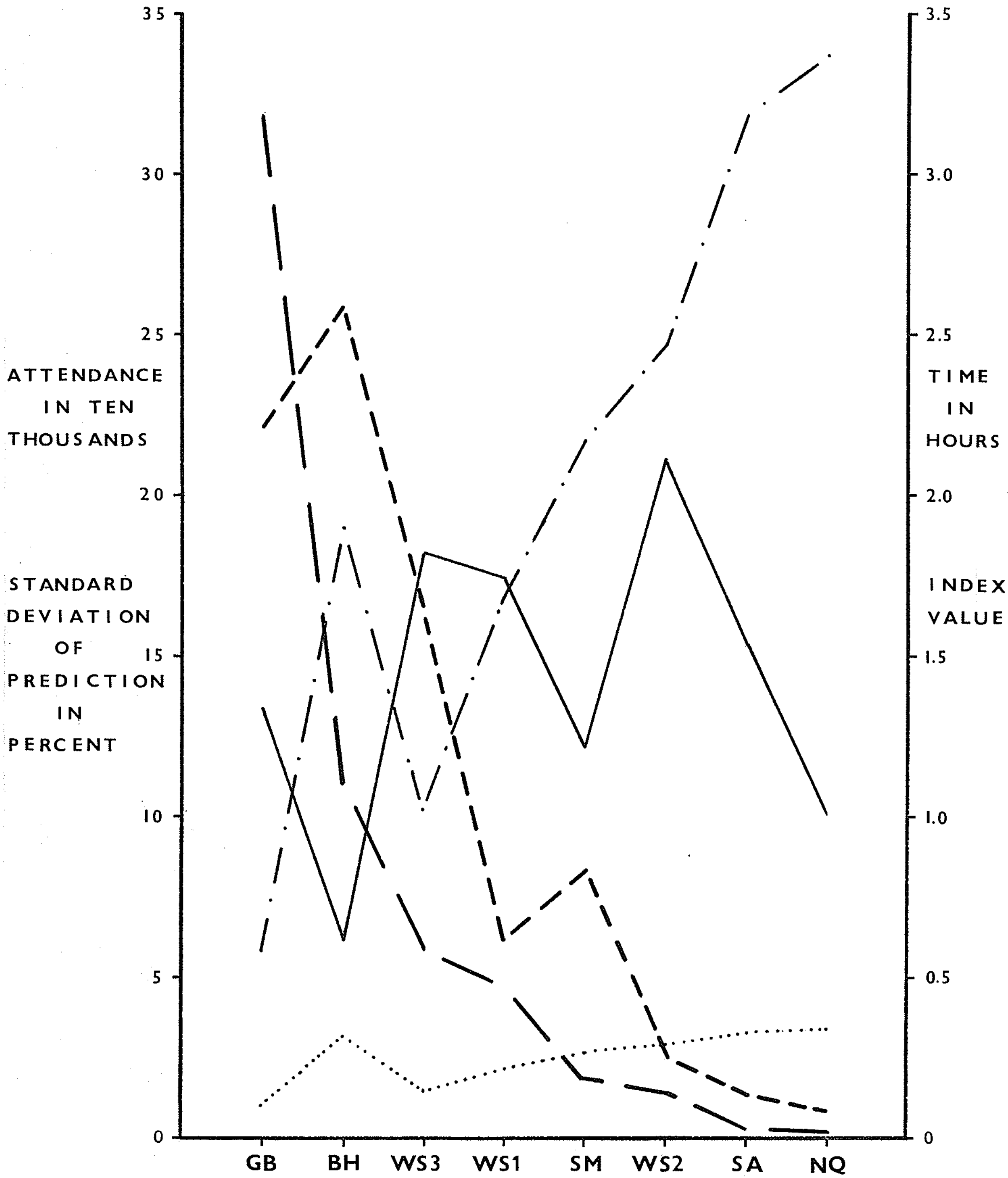

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FIG. 4

LEGEND FIGURE 4

GB - Grand Beach

BH - Birds Hill

SM - St. Malo

SA - St. Ambroise

NQ - Norquay

WS1 - Whiteshell 1

WS2 - Whiteshell 2

WS3 - Whiteshell 3

- - - - - Attraction index values

---------- Attendance values

-·-·-·-·- Standard deviation of prediction with a 100% change in index

__________ Travel time to each park

.... Standard deviation of prediction with a 10% change in index conclusions can be made. Even with large data error the mean percentage changes (see Table III-5) are quite low and offer some hope of better results once data collection techniques are improved.

CHAPTER IV

CONCLUSIONS

"Since most planners do not claim to be clarivoyant, forecasts of future behaviour can be at best only intelligent estimates. Nevertheless, there are steps a planner can take to see that the maximum of established fact and minimum of intuition one used in making projections."[53] Present methods of isolating an attraction index for recreational facilities depend to a large extent on intuition and do not attempt to use that data which can be considered established fact. Over use of intuition is demonstrated by the work of C. S. Van Doren. As with most attempts at the isolation of attractiveness of facilities Van Doren has independently decided upon those features of facilities that he deems significant with little or no behavioural insight apparent.

Van Doren's technique involves the use of a large number of indicators of attractiveness as chosen by the author. These features are mainly types of facilities present at the recreational area (eg., boat ramps, swings, campsites, etc.) and environmental characteristics of the site (eg., water quality, vegetation, beach size, etc.). Each of these characteristics is assigned a certain value to enable mathematical analysis to be undertaken. Although the method seems to produce the desired results there are several problems associated with its use that

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53 Michael Chubb, Outdoor Recreation Planning in Michigan by a Systems Analysis Approach, Part III: The Practical Application of "Program Recsys" and "Symap", Recreation Resource Planning Division, Michigan Dept. of Conservation, Techn. Report No. 12, December, 1967, Lansing, Michigan.

indicate the results would most likely be spurious.

The basis of Van Doren's work are _A priori_ subjective choices of the variables which compose the attractiveness index. He attempts to choose those features which indicate the individual recreator's perception of the attractiveness of a facility. Yet sufficient data is not available to allow accurate estimates of the individual recreator's choice through the perception-decision process, when deciding upon the trip destination. There is no reason to believe that all the necessary variables are taken into consideration. In fact Van Doren admits that certain important variables are overlooked (eg., situation).

Once the variables are chosen, a second subjective approach is taken, that of scaling. In order to enable the use of mathematical techniques each variable or set of variables is assigned a value deemed to indicate the relative attractiveness of each. This procedure involves three major drawbacks. The majority of the characteristics used by Van Doren cannot be readily scaled on an interval scale. In other words, there is not sufficient information available on recreator preferences to allow parametric scaling of such variables as vegetation and terrain, yet several of the variables are scaled in this manner. This leads directly to a second and equally important disadvantage. If variables are being scaled in this manner the values assigned to them are dependent upon the individual performing the scaling. Since user preference information is lacking, operator variance in the scaling technique causes further error in the results. This point has been demonstrated in the work of J. B. Ellis.

Each of the above problems accumulate in the mathematical analysis. The technique used in principal axis factor analysis. In order that reliable results are obtained all the variables used must be measured on an interval scale. In Van Doren's work twenty-two of forty-one characteristics used are scaled by these unreliable techniques. Thus the meaning of the results of his model is unknown.

This thesis has offered an alternative approach to those presently in use for the isolation of attraction indices of recreational facilities. This approach can be accurately labled a behavioural method as distinct from the non-behavioural approach now used. The reverse tack is taken from the traditional methods. Instead of attempting to predict the behaviour of the recreator, the known behaviour of the population of recreators is utilized in conjunction with the configuration of the recreational system. Attendance rates at the recreational facilities are considered to indicate the relative attractiveness of each facility in relation to the other facilities. By applying these known values to the known configuration of the system accurate atraction indices can be isolated for each facility.

The observable behaviour of the population of recreators combined with the observable features of the recreational system provide three significant data sets:

1) the travel times from the origin to the destination

2) the total participation or use values within the system

3) the individual participation or use values at each destination

By applying these to present trip distribution models only one unknown variable remains, the attractiveness index. Thus by using known data for previous years this index can be isolated. Since the value of the index is generated by the behaviour of recreators in the system, it would be a composite factor incorporating the effect of the situation of the facility, the capacity of the facility and the effects of both travel time and intervening opportunities as presented to the population of recreators. By assuming the effect of these four variables in one measure the problems associated with their separate measurement is removed.

The uncertain results offered by contemporary methods, such as Van Doren's, are significantly reduced by the behavioural approach. The number of independent decisions involved are reduced to the selection of the appropriate model for isolation, thereby increasing both the accuracy of the results and the efficiency and time for isolation of the index.

An effective tool for the recreation planner was one of the major objectives of Van Doren's work. To be able to forecast the attractivity of a new recreational facility through the man-made and environmental attributes of the facility would certainly enhance a planners' ability to produce facilities of higher quality. However, to attack the problem from Van Doren's point of view does little to further this aim. Without knowing the relative attractiveness of present facilities only half-blind qualitative attempts can be made at the estimation of the effect of the qualities of the environmental features of each facility. The introduction of a behavioural index gives the planner a tool upon which decisions can be based.

Further research based upon the behavioural index must involve a more detailed investigation of those considerations to be made about sites. Simple attempts at listing features found within facilities is not adequate. The recreational facility must be considered as an environment specifically designed for the recreational purposes of man. The planner should look upon man as a recreative organism and investigate aspects which affect or control his recreational behaviour. A framework must be developed within which man as the recreator is the central figure and through this framework investigations of the makeup of the attractiveness index can be conducted.

Such a framework based on man as a recreative organism must consider the reasons for recreation, the importance of either physical or mental relaxation. In order to develop this aspect the perceptual environment of a facility must be investigated. The recreator's perceptual environment could be based upon three main features:

1) the visual aspect of the facility

2) the comfort aspect of the facility

3) the privacy aspect of the facility

To be attractive the recreational facility must be visually attractive. Considerations of the visual field of the recreator must be investigated. Such aspects as slope, vegetation and water areas combine to form the visual attractiveness of a facility. Comfort plays a main role in relaxation. The amount of shade area available, water temperatures for swimming and some man-made facilities are some of the features that can be investigated. Closely associated with comfort aspects is privacy. Recreators vary in their need for privacy, thus varying types of areas allowing varying amounts of privacy are important features of attractiveness. It is necessary to go beyond simple listing of physical features and to build these features into a framework from which specific conclusions can be drawn.

To accurately find the importance of each feature within this framework more controlled conditions than present recreational facilities are needed. Future research into attractiveness could use controlled experiments of each aspect in order to obtain better data with which to investigate the values of attractiveness of recreational facilities as isolated by the behavioural method.

As can be seen in the previous discussion, the behavioural attraction index is only a base from which can begin further investigations of the attractiveness of recreational facilities. The majority of work, to this end, still remains. The index gives planners a tool with which to predict flows within a stable recreational system but does not allow predictions of use at proposed facilities. It is necessary to conduct the suggested research before these predictions can be accurately made. Given an accurate index of known facilities the planner is able to investigate the underlying reasons for the relative values in the system.

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APPENDIX A

The purpose of this appendix is twofold, firstly, to indicate by a mathematical example the exact workings of the network analysis model for prediction of attendance at recreational facilities and secondly, to demonstrate that the program used for this thesis operates correctly. The second objective is necessary due to the intricacy and difficulty of modifying the "RECSYS" program for use in all studies and not just those related to the State of Michigan for which it was developed. The following example is taken from the results of one run of this modified program.

The hypothetical park system used consists of a single origin city (X) and four equidistant and equiattractive recreational facilities (A,B,C,D) as shown in the systems graph in Figure 5. Each of the edges of the systems graph is identified by a number from one through nine and the direction of flow along each is indicated by an arrow. Edges 5,6,7,8 and 9 are each connected to a common node which is not shown. The following cutset equations were obtained from the graph

BRANCHES	CHORDS	ORIGIN
8	2,3,4	5
7	-3	-
6	-4	-
9	-2	-
1	2,3,4	5

These equations indicate the conectivity of the graph and these equations along with the following data are the input for the model.

SCHEMATIC DIAGRAM OF A HYPOTHETICAL RECREATIONAL SYSTEM

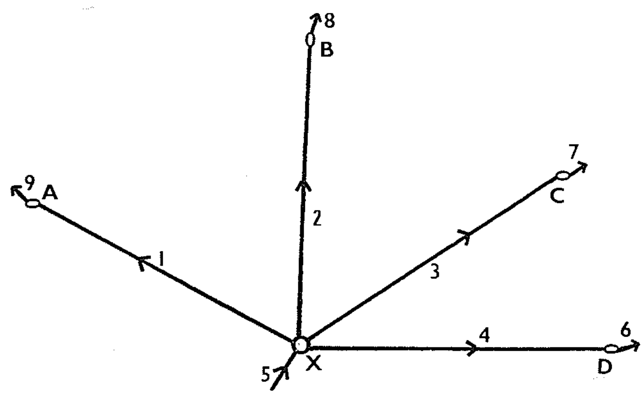

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FIG. 5

LEGEND FIGURE 5

A,B,C,D - Destinations

X - Origin

LINK RESISTANCE AND SPEEDS

LINK	RESISTANCE	SPEED
1	6	1.0
2	6	1.0
3	6	1.0
4	6	1.0

DESTINATION ATTRACTION AND CAPACITY VALUES

DESTINATION	ATTRACTION	CAPACITY
A	1.0	1.0
B	1.0	1.0
C	1.0	1.0
D	1.0	1.0

EXPECTED DESTINATION FLOW VALUES

DESTINATION	EXPECTED VALUE*
A	100
B	100
C	100
D	100

FLOW FROM THE ORIGIN (X) = 400

*Since the destinations are equidistant and equiattractive, the expected total trips to each destination is equal to the flow value from the origin divided by the number of destinations ($\frac{400}{4} = 100$).

The model calculates the flow through the four destination edges (6,7,8,9) by translating the cutset equations into simultaneous equations utilizing the link (1,2,3,4) resistances and the attraction and capacity values for the destinations. The first step produces an array of these values as follows:

Each of the destination edges is assigned a value equal to the attraction of the destination times the capacity of the destination. The second step utilizes an equation for calculating the link conductances as follows:

$$E(I) = \frac{a}{\left(\frac{\text{Distance}}{\text{Speed}}\right)^{b}}$$

where: E(I) = link conductances

a,b = constants

In this test case both a and b are equal to 1.0. The array resulting from these two steps is:

	EDGES	CONDUCTANCE
destination edges	6	1.0
	7	1.0
	8	1.0
	9	1.0
links	1	0.167
	2	0.167
	3	0.167
	4	0.167

These values are now translated into simultaneous equations for solving the systems flows. A matrix is formed such that: the diagonal elements equal the positive sum of the values of the edges in each cutset and the off-diagonal elements equal the sum of the coincident edges among the cutsets. The following matrix is realized from the above data and cutset equations:

$$G = \begin{bmatrix} 1.500 & -0.167 & -0.167 & -0.167 & 0.500 \\ -0.167 & 1.167 & 0.000 & 0.000 & -0.167 \\ -0.167 & 0.000 & 1.167 & 0.000 & -0.167 \\ -0.167 & 0.000 & 0.000 & 1.167 & -0.167 \\ 0.500 & -0.167 & -0.167 & -0.167 & 0.667 \end{bmatrix}$$

Note that the matrix is symmetrical and that the number of rows and columns is equal to the number of cutset equations. The solution vector for these equations is an array of the origin flow value where the origin appears in the cutset equations:

SOLUTION VECTOR
400
0
0
0
400

The equations are solved by inverting the matrix (G) and multiplying the inverted matrix (G^{-1}) by the solution vector and then by the vector of edge conductances:

$$\text{Flows} = G^{-1} \cdot S \cdot C$$

where: S = solution vector

C = conductance vector

$$\text{Flows} = \begin{bmatrix} 0.893 & 0.036 & 0.036 & 0.036 & -0.643 \\ 0.036 & 0.893 & 0.036 & 0.036 & 0.214 \\ 0.036 & 0.036 & 0.893 & 0.036 & 0.214 \\ 0.036 & 0.036 & 0.036 & 0.893 & 0.214 \\ -0.643 & 0.214 & 0.214 & 0.214 & 2.143 \end{bmatrix} \cdot \begin{bmatrix} 400 \\ 0 \\ 0 \\ 0 \\ 400 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 0 \end{bmatrix}$$

The results were as follows:

DESTINATION	PREDICTION	EXPECTED VALUE
A	100	100
B	100	100
C	100	100
D	100	100

The standard deviation of prediction is zero. Therefore, from these results it can be concluded that the modified network analysis program is working accurately.