OPTIMAL ALLOCATION OF RECREATIONAL ACTIVITIES WITHIN A RESERVOIR AREA UTILIZING TOPAZ

by

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I. INTRODUCTION

The existence of recreational facilities, such as boating, camping, picnicking and swimming, have a great impact on the visitation tendencies at reservoir projects. By the intelligent planning of the location and size of the planned facilities, the planner has at his disposal a means of controlling the present and future growth of recreational areas. The growth or development potential of reservoirs is determined either by the prospective visitation or by the amount of "usable" land available. In either case the planner should, as part of his goal to achieve optimum development, find the proper allocation of recreational activities to specific areas to minimize the total construction cost and at the same time maximize the benefits to the users. Due to the lack of empirical planning tools, decisions concerning recreational development have previously been based on a prior knowledge of development trends and in some cases the general experience of planners.

In order to introduce a more systematic aspect to urban planning, there is presently a trend to develop mathematical models to aid in the planning and development of urban areas. These models are useful tools to aid the planner in making decisions regarding alternative development planning strategies. One such model now in use is TOPAZ which is the technique for optimal placement of activities in zones. The model was first developed under this name by Brotchie, Toakley and Sharp (5) for the use in general urban planning and has been modified to some extent by J. W. Dickey of the Virginia Polytechnic Institute and State University. The model was originally developed to determine the optimal allocation of a set of activities in certain zones or areas and at the same time maximize the benefits occurring to the pattern of development. While the TOPAZ Model is a useful and workable tool for testing various urban development alternatives for an area, the model has not been used in the development of recreational facilities adjacent to a proposed or existing reservoir. This research is concerned with determining if TOPAZ can be a useful and practical tool for recreational development and if so, the methodology necessary for its use.

Study Objectives

The objectives of this research are as follows:

1. Formulating the problem.
2. Constructing a mathematical model to represent the system.
3. Obtaining a solution.
4. Testing the model.
5. Putting the model to work, or implementation.

The simplest case which was deemed possible as an example of the TOPAZ model involves the optimal placement of four key recreational activities in an area consisting of six zones. For the purpose of this research it was not considered necessary to include all of the recreational activities that are considered when evaluating the recreational potential of an area. Therefore, only the necessary input and the resulting outputs for the four key activities will be presented along with a thorough discussion of the theory of operation of the technique.

II. REVIEW OF THE LITERATURE

Recreation Defined

In order to satisfactorily discuss recreation and the importance of the location of recreation facilities, it was considered appropriate to define the word recreation and the history of its development. The word recreation is subject to a large number of interpretations and definitions. The meaning can lie solely in the concepts in which it is used and by the person using it. For example, hunters have an entirely different understanding of the word than do swimmers. That is to say that the desires of hunters are often incompatible with the desires of swimmers. Many people would state that recreation is merely having fun or receiving some enjoyment from some activity which varies from the routine of their daily lives. Recreation is usually thought of as an activity but would be a planned inactivity as well (3).

Probably, the most useful or meaningful definition is found in Economics of Water Resources Planning by L. Douglas James and Robert R. Lee, where they define recreation as an activity or inactivity which "provides physical, mental and emotional rejuvenation through relaxation made possible by relieving the strain of doing what one has to do" (10, p. 395).

History of Recreation Development

Throughout the history of man, recreation has been a major part of his life. Recently, a growing concern for the availability of water-based-recreation facilities has resulted from its increasing demand. The first Federal action to provide an area for recreation activities was in 1864 when Congress placed Yosemite under the control of the State of California and in 1872 Yosemite became the first national park. Because of its distance from urban development, the visitation to Yosemite was low. However, as the mobility of the population increased, visitation increased and with it there was an increase in the demand for recreational opportunities.

Between 1933 and 1937 T.V.A., realizing the future demand for recreation opportunities, constructed six model parks. These parks demonstrated the potential of such areas to provide swimming, boating and other water-based activities and to enhance other recreational activities such as picnicking and camping. In 1916, Congress passed the proper legislation to establish the National Park Service as part of the Department of Interior and gave it the responsibility of administration of all national parks and monuments (2).

In 1944 the first formal recognition of recreation as part of water resource development came about through the passing, by Congress, of the Flood Control Act of 1944. This act authorized the Corps of Engineers to construct and maintain recreational facilities at future reservoirs which showed a potential for such development. This act also stated that the facilities were to be open to the general public with no charge for admission which set a precedent for free use of the developed facilities (13).

During the period of 1944 to 1957, efforts were made to pass legislation that would allow recreation to be included as a project purpose in all future reservoir construction. All efforts during this time were defeated, primarily due to the opposition of those who felt that the inclusion of recreation as a project purpose would eventually lead to the authorization of projects that were not previously economically justified. There was already a backlog of public works projects competing for federal funds and it was felt that emphasis should be placed on projects which would provide relief from flood control problems and navigation difficulties to those persons seeking it. As visitation and the demand for recreational opportunities increased, the need for recreational areas was realized. The Outdoor Recreation Resources Review Commission (ORRRC) was formed in 1958 to review the lack of or the need for recreational development. The ORRRC report which was submitted to Congress in 1962 recommended the creation of a Recreation Advisory Council and a Bureau of Outdoor Recreation (BOR). In March of 1962, Senate Document 97 was enacted. This document provided that outdoor recreation and fish and wildlife opportunities should be provided where they enhance the development of a multiple use project (11). It stated that:

> "Full consideration shall be given to the opportunity and need for outdoor recreational enhancement in comprehensive planning for water and related land use development, and project formulation and evaluation" (15, p. 6).

Following Senate Document 97, the Ad Hoc Water Resources Council published Supplement No. 1 (1) in June of 1964. This publication provided uniform standards and terminology for the determination of the outdoor recreational benefits at water and related land resource development projects. Public Law 89-72, which is the current legislation regarding recreation at federally authorized projects, was passed in July of 1965. This law updated Senate Document 97 and stated that full consideration should be given to recreation as a project purpose when the project can provide outdoor recreational opportunities (13). During the period from 1944 to 1965 recreation benefits changed from intangible extra dividends to "bona fide" tangible benefits.

Role of the Government in Recreation

One might be able to justify the federal government's concern with recreation because of its "public goods" aspect. A public good can be defined as a good which obtains three basic characteristics. One is non-exclusibility, another is jointness in consumption and the third is inability to enforce payment. An example of such a good is national defense. Although some recreational facilities have public good characteristics, recreation in the strict sense does not fit this description. Recreation can be compared to police protection and hospitals which are provided by the use of public funds to be used by all in equal amounts, but the use of these by one individual detracts from that which is available for use by others. Recreation can be compared to hospitals in the sense that what is provided is the ability to accommodate visitors.

Recreation has been provided by the public sector in an economical manner, but without regard to the optimum allocation of our natural resources. The private sector only provides restricted forms of recreation and the supply is only available to the class of people who are willing and able to pay. Privately owned recreational areas are operated to make a profit without regard to the demand for all types of facilities and the preservation of our natural areas. The Federal Government should therefore step in and pursue recreation as part of its program of water resources development in order to reach a point so "that there will remain no possible reallocations, no shifts in inputs, outputs and in distribution such as would make one or more individuals better off in terms of their own preferences without making some other individual worse off in terms of theirs" (12, p. 120).

The Need for Recreation Facilities

As per capita income increases and the work week becomes shorter, more and more Americans are going to spend greater amounts of money to make their leisure time more enjoyable. Recreation is becoming more popular in the U. S. as a way of life mainly because it is increasingly possible for larger numbers of persons of modest income to participate in leisure outdoor activities. It has been estimated that by the year 2000 the real income per capita will be around $4,000 compared to $2,000 in 1964 (6). With the increase in ownership of automobiles and the improvement of the highway system, the mobility of the general public has been enhanced greatly. The reports of the Outdoor Recreation Resource Review Commission emphasize four major influences that will increase the use of our recreation facilities. They are (1) more leisure time, (2) rising real income, (3) greater family income and (4) more extensive advertising. These factors not only will result in an increase in use of existing facilities but will also create an increasing demand for new facilities.

Studies made by the Bureau of Outdoor Recreation show that there has been a sharp increase in popularity of outdoor recreation during the period 1960 to 1965. Projections made by BOR show that by the year 2000 there will be an increase in recreational occasions of 400 percent over that in 1960. This is an increase from 4,282 million occasions in 1960 to approximately 16,842 million occasions in the year 2000. The general increase in millions of occasions of participation in major summertime outdoor recreation activities is shown in Figure 1 (18).

The Bureau of Outdoor Recreation studied 16 major outdoor activities and showed that of the five activities with the greatest percentage increase in future use, three were major water-oriented activities. By the year 2000 it is anticipated that swimming occasions will increase by 207 percent, camping 238 percent and boating 215 percent. Associated with boating, water skiing showed the highest increase in future participation with an increase of 363 percent over 1965 by the year 2000. Swimming is becoming so popular as an outdoor activity that by the year 1980 it will become our number one outdoor recreation activity and will continue to hold that spot in the year 2000.

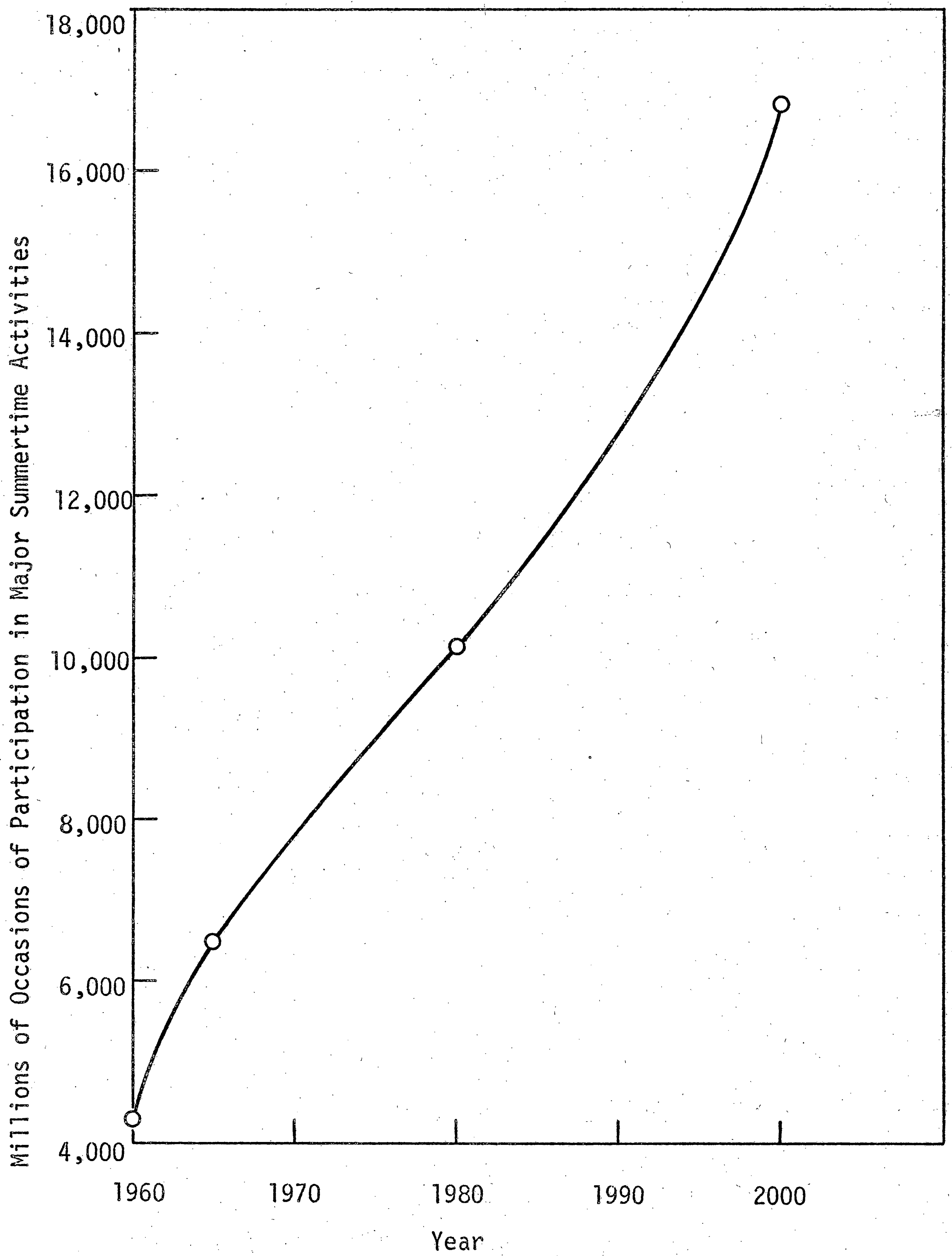

Figure 1. Participation in Major Summertime Outdoor Recreation Activities (18).

Figure 2 shows the projections by BOR of the four major outdoor recreation opportunities (18). It is evident that there is a growing concern for the supply and demand of recreation facilities. One author states that "perhaps the greatest single problem facing the average United States citizen today is good, socially acceptable use for his leisure time" (2, p. 386). Associated with the increasing need for recreation facilities is the responsibility of the various governmental planning agencies to provide these facilities for optimum public use at the lowest possible public cost.

Present Method of Placing Recreational Facilities

During the preliminary design stages of comprehensive river basin planning, proposed locations of potential reservoir sites are established. The reservoirs are then screened by using the benefit-cost procedure and only those reservoirs showing potential economic justification are studied further.

After the location of the dam site is determined, the benefits that would accrue from the construction are evaluated. An evaluation is made at various pool elevations to determine the optimal height to which the dam should be constructed. Thus a marginal evaluation is made of the cost and benefits and the project justification is determined.

To evaluate the recreational potential of a proposed reservoir site, the pool size is determined by use of topographic maps. The dam site is then visited and by using personal judgement and past experience,

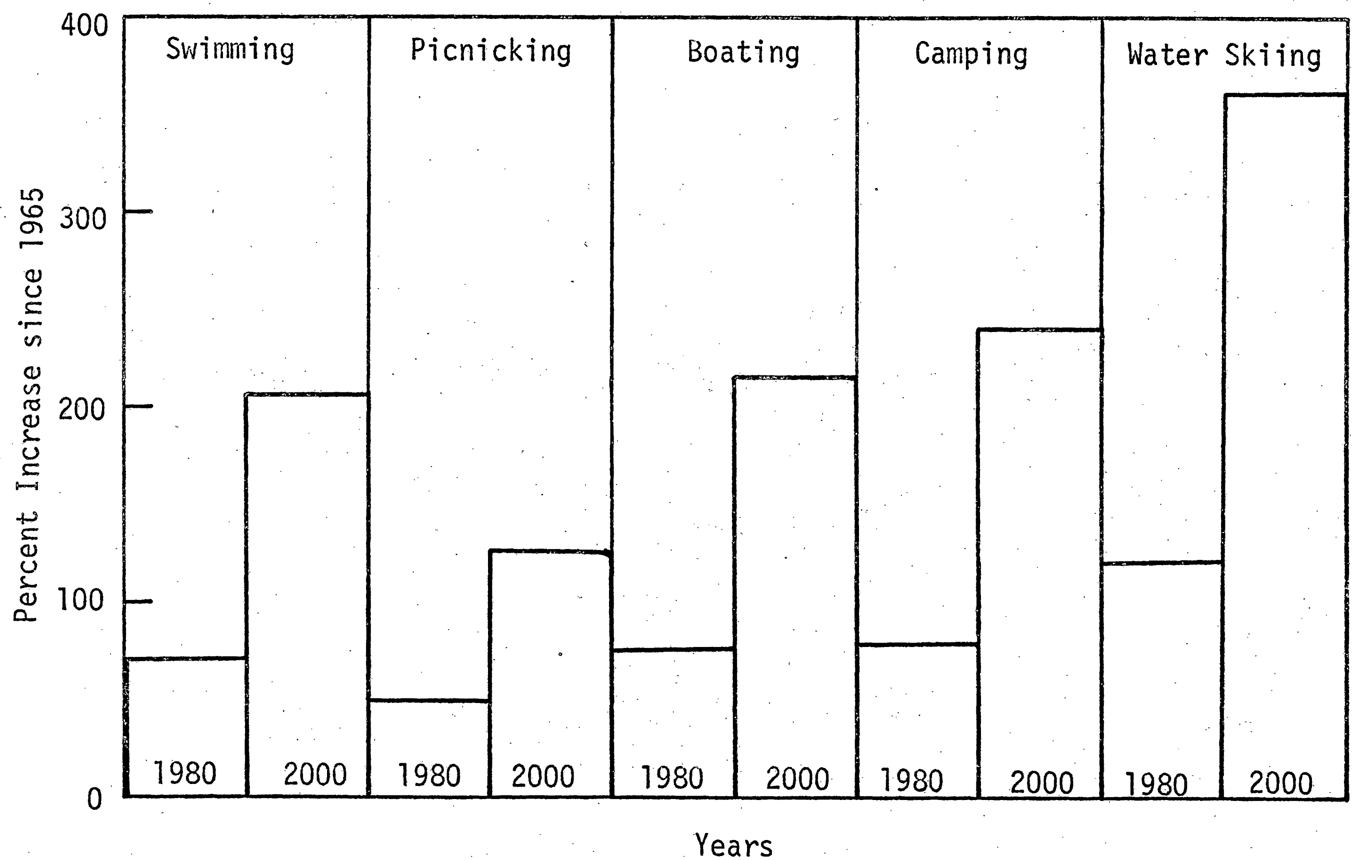

Figure 2. Expected Increase in Recreational Activities

the amount of usable land is determined. The amount of usable land is used to determine the potential annual visitation to the reservoir in question. The average requirements for a normal reservoir-oriented mix of recreation activities is about 100 acres for each 100,000 annual visitors. This figure was calculated by use of data compiled from reservoirs now in existence.

Next, the areas with potentially developable land are evaluated by the use of past experience and personal judgement, in order to determine which areas are best suited for development of certain recreational activities. Major consideration is given to average slope of the area, accessibility to water, aesthetics, vegetation and access to the area. The estimated cost for recreation as a purpose of potential projects is based upon the theoretical annual attendance of 100,000 and land requirement of 100 acres. Costs include recreation facilities, circulation roads, water supply and sanitation. Using the annual attendance per 100 acres of developable land, the design load is computed by using available formulae.

Cost estimates for development of typical recreational facilities have been computed and reduced to a cost per visitor day. By using the design load and the cost per visitor day, a final recreation cost can be obtained. This method can be used for estimating the cost of providing facilities for both the initial and ultimate visitation. After the costs have been determined and the benefits evaluated, both are reduced to an annual base and are compared to determine if there is economic justification for inclusion of recreation as a project purpose.

Development of TOPAZ

As the world's population continues to grow and urban areas continue to expand, proper urban planning has become increasingly important. Many researchers have tried to develop planning models that could be used as a tool to aid in the best allocation of activities and at the same time minimize the cost of developing and using these activities. Until the development of A General Planning Model (4) by Brotchie in 1969, the results were not overly successful. The model proposed by Brotchie was a general econometric planning model that would provide an allocation of certain set activities in a given set of zones. It was developed with potential application toward national, regional and urban development and could be further applied to industrial development, building layout and building design. The model, as proposed by Brotchie, provided an objective function which consisted of an establishment cost (the cost of constructing an activity in a certain area) and a travel cost (the cost of travel between the allocated activities). The model was based on the concept that changes in the allocation of activities in certain areas and changes in the methods and routes of transportation would result in an increase in merit to the potential users. The increase in merit or benefit received by a change in allocation patterns was combined with the cost of placing each activity in each zone. The model was constructed so as to select a_{ij} to maximize a measure of benefit $U(a_{ij})$. The model, as derived by Brotchie, would optimally allocate certain activities to certain zones based on a comprehensive cost-benefit function. The general planning model as proposed is:

Maximize a measure of merit $U(a_{ij})$ where

$$U(a_{ij}) = \sum_i \sum_j a_{ij} \; b_{ij} \; A_i + \sum_i \sum_j \sum_k \sum_l a_{ij} \; a_{kl} \; b_{ijkl} \; S_{ik} \; R_{jl}$$

Subject to

$$\sum_i a_{ij} \; A_i \leq Z_j$$

$$\sum_j a_{ij} = 1$$

$$a_{ij} \geq 0$$

in which

a_{ij} is that fractional portion of activity i allocated to zone j

A_i is the size of the ith activity

Z_j is the size of the jth zone

S_{ik} is the interaction level between activities i and K or the cost per mile travelled per unit time

R_{jl} is the length of path between zones j and l by any pre-allocated route

b_{ij} is the sum of the benefits less the cost of establishing and operating one unit of activity i in zone j

b_{ijkl} is the sum of the benefits less the cost of establishing and operating one unit of interaction S_{ik} along one unit of path R_{jl}.

Following the development of the general planning model, R. Sharpe, J. F. Brotchie and A. R. Toakley made a study to determine usefulness of the model discussed above. The study, Use of Systems Techniques in Urban Planning, (5), shows the general procedures necessary for use of the planning model. During the study, the model was translated into a computer program called TOPAZ (Technique for the Optimum Placement of Activities into Zones). The computer program developed to compute the basic objective function was combined with readily available optimization techniques to determine which allocation would lead to the most desirable area development. TOPAZ, as it was developed, will identify both the location and magnitude of the proposed development necessary for the achievement of the most desirable distribution of land uses. It was noted that, at the current stage of development, TOPAZ does not always give a "global optimum" solution or that solution which, when obtained, is the maximum or minimum solution obtainable for the given objective function. In some cases the solution obtained is that which is referred to as a "local optimum." The problem may be best defined by comparing the solution to trying to find the highest point in a mountain range. The height of each mountain could be considered as a "local optimum" and the height of the highest mountain, the "global optimum." Therefore, TOPAZ should be considered only as a tool to aid in planning, with the final decision as to the activity allocations left to the judgement of the planner.

TOPAZ has been shown to be useful in other areas of planning. In a report by Dickey and Hopkins (8), it was shown that TOPAZ is a useful planning tool in the development of college campuses. In this study, the computer program for the objective function was combined with available minimization techniques to determine the campus building arrangement pattern which would result in the minimum amount of travel between activities. This study further shows the potential of TOPAZ as a planning tool. The study demonstrates the versatility of the technique and gives insight to how the procedure can be applied to other areas of the planning profession.

III. PROCEDURE

Development of the Model

While TOPAZ has been proven to be a useful and workable tool for testing various alternative decisions in different types of urban systems which might be provided within a given area, the technique has not been applied to the determination of which of various alternatives would be best or optimal for planning of water based recreational activities. It is believed that this technique would be a valuable tool to aid the recreational planner in obtaining the best allocation of activities, and thus find the best solution that would lead to the most desirable development. This technique will identify both the location and magnitude of recreational activities necessary for the achievement of the best distribution of land uses within each zone of a reservoir area.

The model includes the two basic cost components which are considered when evaluating the potential of an area for recreational use. The two are the establishment cost or the cost of placing each activity in each zone, and the network construction cost or the cost of providing access to each zone. Also included in the model and not usually considered as a project cost, is the cost of travel that would accrue from the use of the planned facilities. The travel, although not a part of the total project cost, should be given some consideration when planning recreational facilities; but the major purpose for its inclusion in this model was to cause the activities to tend to group into one general area. Although people tend to visit reservoir areas with one primary recreational purpose, the interaction between activities is usually what accounts for about 40 percent of the total recreational occasions. Thus, some factor must be included to cause the activities with a high degree of interaction to group together, thereby allowing for the optimal use of the facilities. Although the allocation technique will provide a feasible outlay of activities without travel being included, the distribution would, in most instances, be impractical. This is because the alternative with the smallest cost does not take into account the relationship of one activity with another.

The format of the recreation layout problem can be represented by the following mathematical model:

$$\text{Min. } Z = \sum_{j}^{m} \sum_{i}^{n} C_{ij}\ ACTS_{ij} + \sum_{j}^{m} \sum_{k}^{m} TR_{jk}\ TT_{jk}\ VOT +$$

$$\sum_{j}^{m} RCOST_{j}\ COSFAC_{j}$$

Subject to:

$$COSFAC_{j} \equiv \begin{cases} 0, & \text{if } ACTIV_{j} = 0 \\ 1, & \text{otherwise} \end{cases}$$

$$\sum_{j}^{m} ACTS_{ij} = AA_{i} \text{ for all } i$$

The sum of the acres of activity i allocated to all zones, must equal the future amount of that particular activity to be allocated.

$$\sum_{i}^{n} ACTS_{ij} = BB_{j} \text{ for all } j$$

The sum of the acres of activities allocated to zone j must equal the area available for development in that zone.

$$\sum_{j}^{m}\sum_{k}^{m} TR_{jk} - \sum_{k}^{m}\sum_{j}^{m} TR_{kj} = 0$$

The sum of the trips into any activity must be equal to the sum of the trips leaving that activity.

$$ACTIV_j \equiv \sum_{j}^{n} ACT_{ij}$$

$$C_{ij} \geq 0$$

$$ACTS_{ij} \geq 0$$

$$TR_{jk} \geq 0$$

$$TT_{jk} \geq 0$$

$$VOT \geq 0$$

$$RC_j \geq 0$$

$$AA_i \geq 0$$

$$BB_j \geq 0$$

$$ACTIV_j \geq 0$$

Where

C_{ij} is the cost per acre of placing activity of type i in zone j.

$ACTS_{ij}$ is the number of acres of activity of type i allocated to zone j.

TR_{jk} is the total person trips going from zone j to zone k depending upon the type of activity i allocated to both zone j and zone k.

TT_{jk} is the travel time from zone j to zone k in hours.

VOT is the dollar value of time.

$RCOST_j$ is the cost of providing access to zone j from major access points.

$ACTIV_j$ is the sum of all activities of types i to be allocated in zone j.

AA_i is the acres of activity of type i to be allocated.

BB_j is the acres of land available for development in zone j.

The model allocates a set of activities to a set of zones or spaces to minimize the total sum of costs arising from the allocations. The activities may vary in both type and magnitude and the zones may vary in location, shape and size and may be filled with a mix of activities, one activity, or only partially filled. The model has been translated into a computer program similar to TOPAZ and combined with an available minimization subroutine. The program is similar to the program developed by J. W. Dickey, Virginia Polytechnic Institute and State University, for use in planning for local, regional and national development. A copy of the program, along with a sample of its input is included in the appendix. It should be noted that as in TOPAZ, the resulting allocation may or may not be a global optimum. However, by using this technique the planner can obtain several near optimal solutions from which to choose.

The development of the above model for the allocation or assignment of certain activities is similar to the typical transportation problem format where certain items are to be transported from some supply point to some point of demand at a minimum cost. In this situation, the proposed activities are being "transported" or allocated to certain points of demand so as to minimize the total cost resulting from the allocation.

The technique requires that the planner start with an initial solution for the $ACTS_{ij}$ in the mathematical formula. The initial solution selected should not only be feasible but should also be practical. This is due to the fact that the model does not always give a global optimum solution and a good initial solution will increase the chances of obtaining the best possible allocation of activities.

Selection of Zones

The selection and layout of the zone is left to the judgement of the planner. The zones can vary in shape, size and location. They can be spotted throughout the reservoir area or they can be continuous as assumed for this research. The zones should be selected so one zone will not compete with another for a certain activity. That is, an area with a rugged terrain should be classified as one zone and an area with a relatively flat terrain should be classified as another. In many instances, the zones will be determined by existing development or natural topographical boundaries. In selecting the size, shape and location of the zones, several characteristics should be taken into consideration, and they are listed below:

1. Present road network.
2. Existing development, if any.
3. Topography.
4. Soil conditions.
5. Slope of the area.
6. Tree cover.

7. View or aesthetics.

8. Accessibility to main roads.

9. Proximity to utilities.

10. Accessibility to the reservoir.

For this research, a hypothetical reservoir was used and is shown in Figure 3, along with the zonal pattern selected.

For the purpose of developing cost estimates and showing the general procedure for utilization of this technique, each zone was given certain physical characteristics. Zones 1 and 6 were assumed to be similar in character with both zones being highly suitable for picnicking and camping activities due to an ample supply of relatively flat areas, with good tree cover away from the edge of the reservoir. The banks along these zones are relatively steep and are not naturally suitable for boat launching and swimming areas. Zones 3 and 4 are relatively flat with a minimal amount of tree cover. Both zones would be suitable for developing swimming and boating facilities, but camping and picnicking would be costly due to the additional shelters that would be required. Zone 5 was assumed to have a rugged terrain and is not considered to be naturally suitable for development of any activity. Zone 2 is considered to have the appropriate amount of tree cover and adequate foreshore slopes for picnicking, camping and boating but could not accommodate swimming in its natural state. The area of developable land in each zone is given in Table 1.

TABLE 1

Zones and the Area Available for Development

Zone	Area in Acres
1	18
2	28
3	18
4	17
5	9
6	10
Total	100

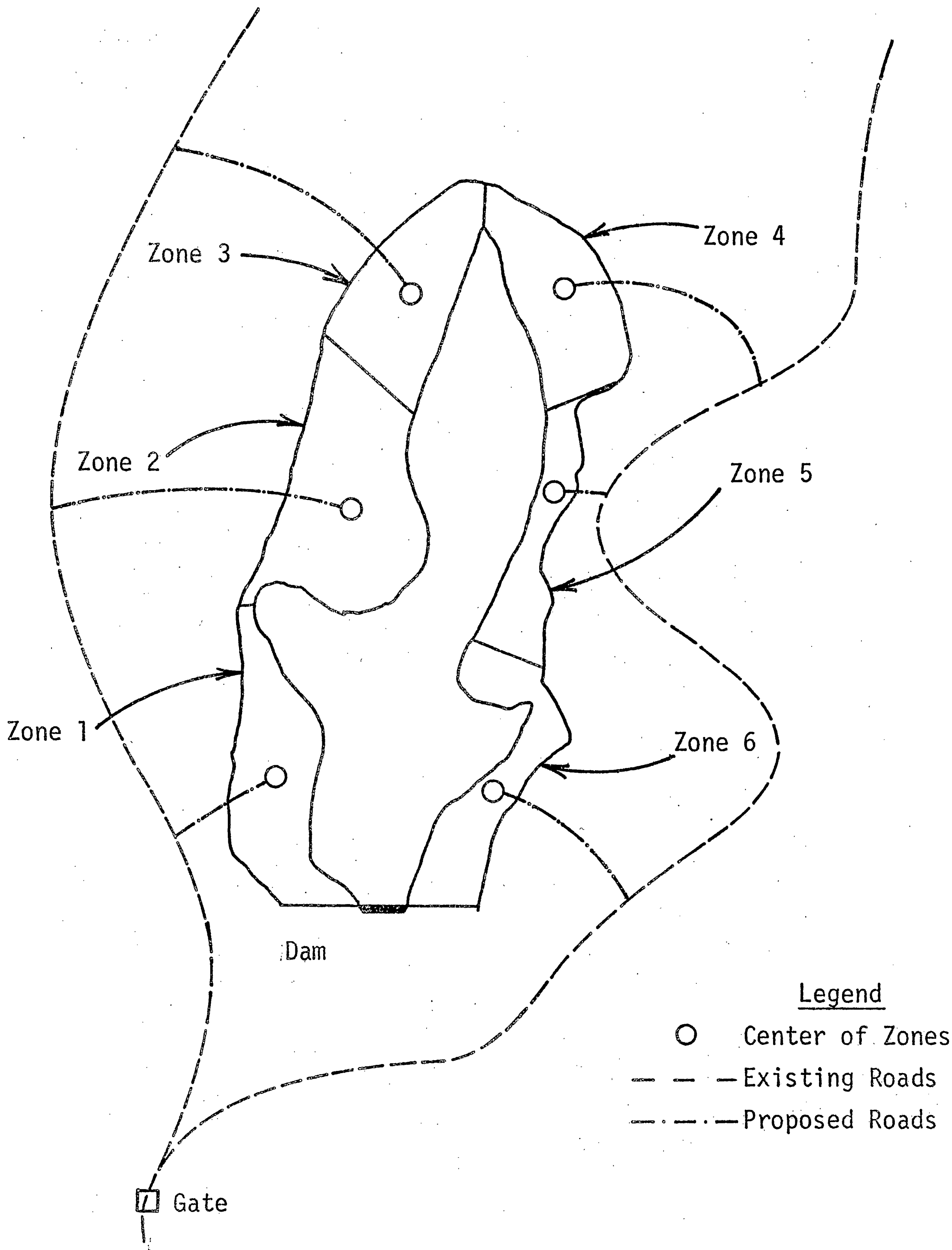

Figure 3. Hypothetical Reservoir Under Study.

Design Criteria

After the quantity of developable land has been determined, it is possible to estimate the total annual visitation, the total design load for the entire recreation complex, and the design load for each individual activity. The design criteria used is that presently being used by the U. S. Army Corps of Engineers in comprehensive river basin planning and is adopted from ER 1130-2-312, Recreation Facilities - Criteria for Design and Construction (7). As stated previously, the total annual visitation for this research is based on the amount of developable area adjacent to the reservoir. Using 100 acres of developable land, an annual visitation of 100,000 was calculated.

To develop the required facilities for recreation, it is next necessary to determine the "total design load" or the maximum number of people expected to visit the area at any one time on a normal summer Sunday. This is the maximum number of visitors for which recreation facilities must be provided. The "total design load" can be calculated by using the equation below:

$$\text{Total Design Load} = \frac{(Y)\ (P)\ (AV)/\ NW}{TO}$$

Where AV = Annual visitation.

P = Percent of annual visitation that will use the facilities during a normal summer season.

NW = Number of weeks of a normal season and is usually estimated as 4-1/2 month period from May 1 through Labor Day in September. This provides a summer season of about 18 weeks.

TO = Rate of turn-over and should be considered for each activity separately. The rate of turn-over may be expressed as the total design load divided by the instantaneous visitation.

Y = Percent of weekly visitation expected on a normal summer Sunday.

To compute the "total design load" it was estimated that 87 percent of all visitation occurs during the summer months and approximately 40 percent of the total weekly visitation will occur on a normal summer Sunday (14, pp. 66 and 69). By using those figures and the formula above, the "total design load" for the hypothetical reservoir being used for this research is:

$$TDL = \frac{(40\%)\ (87\%)\ (100{,}000)/18}{1.0} = 2000$$

The "design load" for each activity is a function of the TDL and is based on a percentage distribution of the total annual visitors that would engage in certain recreational activities. The resulting design loads are for the maximum expected daily visitation. To compute the instantaneous visitation or the expected number of visitors to be at an activity at any one time, the design load must be divided by the estimated turn-over rate. The percent distribution (16), the estimated turn-over rate and the expected instantaneous visitation are shown in Table 2.

TABLE 2

Estimated Visitation

Activity	Turn Over Rate	Percent Distribution	Instantaneous Visitation
1. Picnicking	2	55	550
2. Camping	1	15	300
3. Swimming	1.5	55	730
4. Boating	1.5	15	200

Facilities Required

The comprehensive study of the future recreational needs in the Genesee River Basin listed four major outdoor recreation opportunities that should be considered in project planning. They are boating, camping, picnicking and swimming. These activities were selected because "they are considered key planning elements in current park development practices including outdoor recreation developments at water resource projects" (19, p. B-1). The design requirements given below are included to show the general procedure for obtaining the cost of constructing recreational facilities.

Picnicking. The facilities design per acre for picnicking includes 10 tables, 3 fireplaces, 3 trash cans and site preparation. This will accommodate approximately 50 visitors or 5 people per table. Each picnic area should accommodate about 300 visitors and should include one picnic shelter, with water. Using 50 people per acre, the total design acreage for picnicking is equal to 11 acres without sanitary facilities and 12 acres including sanitary facilities. There should be at least one parking space (10' x 20') for each picnic table provided. To allow enough area for adequate parking and circulation roads, the acreage requirement was increased by 30 percent to 16 acres.

Camping. The acreage requirements for camping is based on 5 sites per acre and 5 persons per site. With a design load of 300 campers, this results in an area requirement of 12 acres. The area should be supplied with 1 table per unit or 60 tables, 1 fireplace for every two units or 30 fireplaces, 1 trash can for every two units or 30 trash cans, and water and sanitary facilities. Parking spaces for each camp site should be provided and should be 20' x 20' or 10' x 40' resulting in 400 square feet per site. As in the acreage requirement for picnicking, the requirements for camping were increased by 30 percent to include parking and circulation roads.

<u>Swimming</u>. The design criteria for swimming areas includes both the bathing and beach area. It is generally assumed that 40 percent of the users are in the water, bathing, at any one time. The required water area is thus calculated at 40 percent of the anticipated instances of daily use times 120 square feet per user, resulting in a bathing area of 35,040 square feet. In the bathing area, it is required that sand be placed on the bottom to a depth 5 feet below the minimum pool elevation. Assuming a maximum drawdown of 10 feet, this results in placing sand to a depth of minus 15 feet below the normal conservation pool. The bathing area should have a slope of about 5 percent. Using a 5 percent slope, a depth of 15 feet, and a required bathing area of 35,040 square feet, a bottom sand cover of 59,400 square feet is computed. The beach area required for 730 users is based on 50 square feet per user for a total beach area of 36,500 square feet. Other items that should be accounted for are site preparation, guard towers, trash receptacles, buoys, water and sanitary facilities. Parking spaces should be provided at a rate of one for every 3 swimmers or about 240 (10' x 20') spaces.

<u>Boating</u>. The expected peak day visitation at launching facilities is 200 visitors. The design requirements for launching facilities is one launching ramp, one boat dock, and parking for every 40 cars and

trailers. Assuming that there will be 4 persons per car, the launching area should contain 1.25 launching ramps and 1.25 boat docks. For this study, only 1 ramp and dock will be provided. In addition to the launching facilities, parking spaces should be provided for 50 cars and trailers, and the spaces should be at least 10' x 40'. The launching ramp should have a slope of 10 to 14 percent and constructed so as to provide optimal use during periods when the reservoir is drawn down.

The criteria listed above is only a general summation and could vary for each reservoir studied. For example, areas with relatively cold climates may not warrant as much swimming area as areas with dry, warm climates. Also, the magnitude of any recreational area would be influenced by the existing facilities in the immediate vicinity. The acreage requirements for each activity are given in Table 3.

Cost Estimates

Upon determining the design loads on the required amount of facilities, the cost of placing each activity in each zone can be determined. For use in the minimization technique, the cost should be converted to an annual cost per acre. Tables 4 through 7 are examples of how the costs were computed. The procedure is similar to that now being used by governmental agencies during project planning.

TABLE 3

Required Area

	Activity	Area in Acres
1.	Picnicking	16
2.	Camping	16
3.	Swimming	3
4.	Boating	1
5.	Vacant land	64
	Total	100

TABLE 4

Cost of Picnicking Facilities

Picnicking

Item	Units	Number	Unit Cost	Total
Site preparation (a)	Acres	13	$ 300	$ 3,900
Tables	each	110	60	6,600
Fireplaces	each	110	30	3,300
Trash cans	each	110	30	3,300
Shelter with water	each	2	5,000	10,000
Sanitation facilities	L.S.	--	10,000	10,000
Water supply (well with pump)	L.S.	--	2,000	2,000
Parking	Acre	1	1,500	1,500
Electrical	L.S.	--	2,000	2,000
Circulation Roads	L.S.	--	2,000	2,000
			Total	$44,600

(a) Includes parking area

TABLE 5

Cost of Camping Facilities

Camping

Item	Units	Number	Unit Cost	Total
Site Preparation (a)	Acres	13	$ 300	$ 3,900
Picnic Tables	each	60	60	3,600
Fireplaces	each	30	30	900
Trash cans	each	30	30	900
Water (well with pump)	L.S.	--	4,000	4,000
Sanitation facilities (b)	L.S.	--	35,000	35,000
Electrical	L.S.	--	3,000	3,000
Parking	Acre	1	1,500	1,500
Circulation Roads	L.S.	--	3,000	3,000
			Total	$55,800

(a) Includes parking areas

(b) Includes showers

TABLE 6

Cost of Swimming Facilities

Swimming

Item	Units	Number	Unit Cost	Total
Site Preparation (a)	Acres	2	$ 300	$ 600
Sand				
Bathing area (b)	C.Y.	2,200	6	13,200
Beach area (b)	C.Y.	1,300	6	7,800
Guard Tower	each	1	150	150
Trash cans	each	3	30	90
Buoy System	L.S.	--	150	150
Water (well with pump)	L.S.	--	2,000	2,000
Sanitation facilities (c)	L.S.	--	50,000	50,000
Parking	Acre	1	1,500	1,500
Electrical	L.S.	--	1,000	1,000
Circulation Roads	L.S.	--	1,000	1,000
			Total	$77,490

(a) Includes parking area

(b) Based on a one foot depth

(c) Includes facilities for showers

TABLE 7

Cost of Boating Facilities

Boating

Item	Units	Number	Unit Cost	Total
Site Preparation	Acres	0.5	$ 300	$ 150
Launching Ramps	each	1	4,000	4,000
Parking	Acre	0.5	1,500	750
Sanitation facilities	L.S.	--	7,500	7,500
Water (well with pump)	L.S.	--	2,000	2,000
			Total	$14,400

The costs were next divided by the number of acres required and multiplied by the capital recovery factor for an interest rate of 6% and an economic life of 50 years. Some allowance should be made for annual operation and maintenance, but it was not deemed necessary for the purpose of this paper. The resulting annual cost per acre for the four key activities are picnicking $200, camping $270, swimming $2,460, and boating $1,830.

Table 8 gives a summary of the annual cost per acre of placing each activity in each zone.

Travel

As stated before, travel costs are not usually computed as part of project cost but are included in the model to cause the activities with a large degree of interaction to group together. The total travel within the reservoir area is based on the ability of certain activities to produce and attract visitors. To compute the production and attraction of each activity, it was first necessary to know the percentage of annual visitors that would participate in each activity. The percentages used are the same as in the section on design criteria and are 55 percent for picnicking, 15 percent for camping, 55 percent for swimming and 15 percent for boating. For an annual visitation of 100,000, this gives a total of 55,000 annual visits to picnicking areas, 15,000 to camping areas, 55,000 to swimming areas and 15,000 to use boating facilities, for a total of 140,000 participation occasions.

TABLE 8

Annual Cost Per Acre
For Placing Activity I in Zone J

	Activity			
Zone	Picnicking	Camping	Swimming	Boating
1	160	220	3300	2270
2	150	200	2980	1780
3	270	270	2460	1830
4	200	270	2460	1830
5	250	340	3300	2280
6	160	220	3300	2270

It was then found that for each activity a certain percentage of the 100,000 annual visitors would come to a reservoir area with a primary purpose of participation in that particular activity (17). It has been determined that of all persons visiting a reservoir, approximately 13 percent had a primary purpose of boating, 15 percent camping, 27 percent picnicking and 33 percent swimming, for a total of 88 percent, thus leaving a total of 12 percent wanting to participate in some other activity than the four being used in this research. To include all visitors in the total travel cost it was necessary to add another activity, sightseeing. It was then assumed that 12 percent of the 100,000 visitors would visit the reservoir area with the primary purpose of sightseeing. Using the 88 percent who wanted to participate in the four key activities and the 12 percent participating in sightseeing, all 100,000 annual visitors were included. In addition to sightseeing, another activity, called "gate" was added so a "from activity--to activity" distribution could be obtained. The activity gate is a point at which all visitors will enter and a point from which all visitors will leave. The location of this point is shown in Figure 3. Neither activity, sightseeing nor gate, has any establishment cost associated with them and neither requires any part of the total developable land.

To aid in the computation of the total annual trips, activities were then classified as either home based activities or non-home based activities according to the visitation pattern associated with them. The activities gate and camping were classified as home-based activities with all other activities being classified as non-home based activities. Following the classification of the activities, the trips were then classified as either home based trips or non-home based trips, with home based trips being trips with either end associated with a home base and similarly non-home based trips being trips with neither end associated with a home base. After the trips were classified as home based trips or non-home based trips, the trips were further broken down to home based trip attractions, home base trips productions, non-home base trip attrations or non-home base trips productions depending upon whether the activity in question produced or attracted the trip. To finally calculate the trip productions and attractions, it was necessary to develop a percent distribution of interactions between all activities. The expected interactions between each activity were first developed. These interactions were based on where one might expect a visitor to go after he has participated in the activity which was his primary purpose in visiting the reservoir. The activities and the expected interaction between activities are shown in Figure 4.

It can be seen that for this research it was assumed that there would be very little or no interaction between camping and picnicking. This is because campsites are equipped with picnicking facilities and campers do not need to travel to picnic areas. Likewise, picnickers are not likely to have the equipment necessary to go camping, otherwise camping would have been their primary purpose. Similarly, it was assumed that there would be no interaction between sightseeing and boating. This assumption was made because it was felt that persons owning boats were not likely to drive around sightseeing with a boat

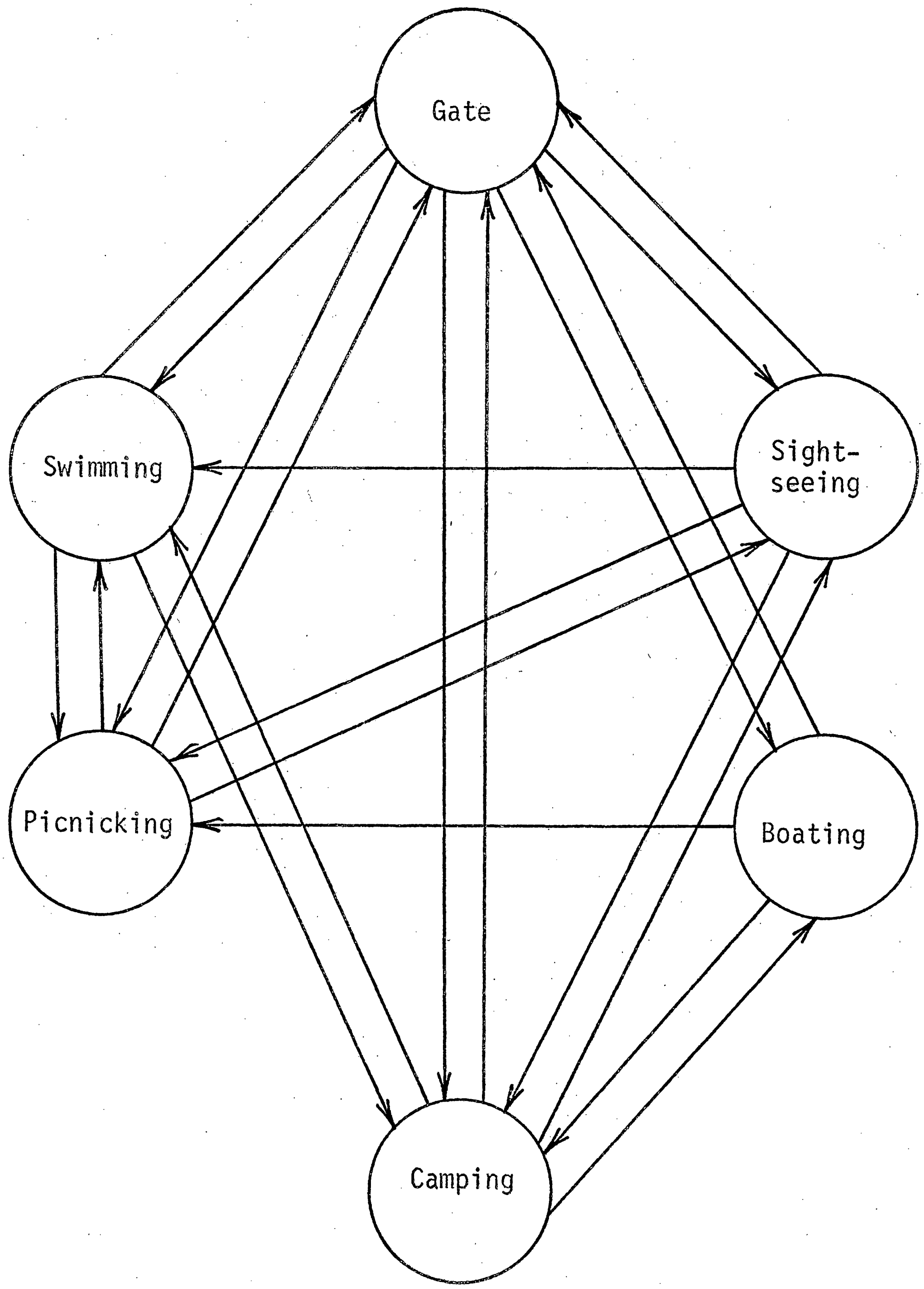

Figure 4. Activities and the Expected Interactions.

attached to their car. Also, it was assumed that there would be no interaction between swimming and boating because persons either swimming or boating are associated with the water and would not tend to travel between the two activities. The interactions between all activities could change depending upon the type of facilities provided. For example, if marine facilities were provided with boat rentals there could be some interaction between sightseeing and boating. Therefore, the interactions between activities would change for each reservoir studied.

Using the interaction pattern of Figure 4, a percent distribution of trips between each activity was formulated. This distribution was based on the total annual visitation and the expected number of persons traveling from one activity to another. The percent distribution of trips and the total annual trips to each activity is given in Table 9.

Using the data developed above, it was then possible to compute the home base and non-home base trip productions and attractions for each activity. The productions and attractions can generally be computed using the equations below:

$$HBA_j = TAT_j \sum_i P_{j,i} + \sum_i TAT_i (P_{i,j}) \text{ for } j =$$

1, 3, 4, 5, and 6 and i = 2 and 7

$$HBP_i = TAT_i \sum_j (P_{i,j}) + \sum_j TAT_j (P_{j,i}) \text{ for } j =$$

1, 3, 4, 5, and 6, and i = 2 and 7

$$NHBA_i = \sum_i TAT_i (P_{i,j}) \text{ for } j = 1, 3, 4, 5, \text{ and } 6 \text{ and}$$

i = 1, 3, 4, 5, and 6.

TABLE 9

Percent Distribution of Trips and Total Annual Trips

From	Gate	Swimming	Picnicking	Camping	Boating	Sight-seeing	Vacant Land	Total Annual Trips
Gate	--	33.0	27.0	15.0	13.0	12.0	0	100,000
Swimming	49.1	--	32.7	18.2	0	0	0	55,000
Picnicking	63.6	18.2	--	0	0	18.2	0	55,000
Camping	46.9	31.3	0	--	6.2	15.6	0	32,000
Boating	73.4	0	13.3	13.3	--	0	0	15,000
Sight-seeing	44.5	7.4	29.6	18.5	0	--	0	27,000
Vacant Land	0	0	0	0	0	0	--	0
Total Annual Trips	100,000	55,000	55,000	32,000	15,000	27,000	0	284,000

$$NHBP_i = TAT_i \sum_j (P_{i,j}) \text{ for } j = 1, 3, 4, 5, \text{ and } 6, \text{ and}$$
$$i = 1, 3, 4, 5, \text{ and } 6.$$

Where

HBA_j is the home base attractions of activity j.

HBP_i is the home base productions of activity i.

$NHBA_j$ is the non-home base attractions of activity j.

$NHBP_i$ is the non-home base productions of activity i.

TAT_i and TAT_j is the total annual trips to activity i or activity j.

$P_{i,j}$ is the percent of trips going from activity i to activity j.

i and j are numerical assignments for each activity as follows:

1 = Picnicking

2 = Camping

3 = Swimming

4 = Boating

5 = Sightseeing

6 = Vacant land

7 = Gate

After the trips have been classified according to production and attraction for each activity, the productions and attractions for each zone can be determined and the total recreational trips computed. To compute the trip productions and attractions for each zone, it was first necessary to add two zones of zero area so all trips could be included. The zones 7 and 8 were added where zone 7 includes all sightseeing and zone 8 includes the gate. The home base trips and non-home base trips for each activity is dependent upon the amount of activity that is being placed in that zone and also if the trips in question are productions or attractions. The home base trips and non-home base trips for each zone can be computed by using the equations below:

$$HMBTP_j = \sum_i ACTS_{i,j} \; HBP_i/AA_i \quad \text{for } j = 1 \text{ to } 6$$

$$HMBTA_j = \sum_i ACTS_{i,j} \; HBA_i/AA_i \quad \text{for } j = 1 \text{ to } 6$$

$$NHMTP_j = \sum_i ACTS_{i,j} \; NHBP_i/AA_i \quad \text{for } j = 1 \text{ to } 6$$

$$NHMTA_j = \sum_i ACTS_{i,j} \; NHBA_i/AA_i \quad \text{for } j = 1 \text{ to } 6$$

Where

$HMBTP_j$ is the home base trip productions for zone j.

$HMBTA_j$ is the home base trip attractions for zone j.

$NHMTP_j$ is the non-home base trip productions for zone j.

$NHMTA_j$ is the non-home base trip attractions for zone j.

Due to the unusual characteristics of zones 7 and 8, that is neither one requires any area, the trip productions and attractions are computed directly. The procedure used for determining the trip productions and attractions for zones 7 and 8 is shown below.

$$HMBTP_8 = HBP_7$$

$$HMBTA_8 = HBA_7$$

$$NHMTP_8 = NHBP_7$$

$$NHMTA_8 = NHBA_7$$

$$HMBTP_7 = HBP_5$$

$$HMBTA_7 = HBA_5$$

$$NHMTP_7 = NHBP_5$$

$$NHMTA_7 = NHBA_5$$

After the trips have been classified and allocated to the appropriate zones, the total trips from zone j to any other zone k can be determined.

Travel Cost

To compute the travel cost, it is required as part of the data input to determine the travel time between each zone. The travel times are computed as the time it requires to travel from the center of some zone j to the center of some other zone k. In reality, trips do not go from center of zone to center of zone, but for the purpose of including travel as part of the model, the error that might be introduced should not be significant. Table 10 shows the computed distance between each zone and the resulting travel times based on an average speed of 20 miles per hour.

By using the trips produced and attracted to each zone, the travel time between each zone, and a unit value of time, (VOT) the total travel cost can be computed.

Road Costs

The road costs are determined by first finding the best route from the existing road network to the center of each zone. These proposed

TABLE 10

Distance and Travel Times Between Zones

From Zone	To Zone 1	2	3	4	5	6	7	8
1	(0) 0	(.36) 0.024	(.61) 0.041	(.85) 0.057	(.80) 0.053	(.47) 0.031	(0) 0	(.59) 0.039
2	(.36) 0.024	(0) 0	(.25) 0.017	(.51) 0.034	(.80) 0.053	(.81) 0.054	(0) 0	(.95) 0.063
3	(.61) 0.041	(.25) 0.017	(0) 0	(.25) 0.017	(.53) 0.035	(.87) 0.058	(0) 0	(1.19) 0.079
4	(.85) 0.057	(.51) 0.034	(.25) 0.017	(0) 0	(.28) 0.019	(.61) 0.041	(0) 0	(1.44) 0.096
5	(.80) 0.053	(.80) 0.053	(.53) 0.035	(.28) 0.017	(0) 0	(.32) 0.021	(0) 0	(.25) 0.083
6	(.47) 0.031	(.81) 0.054	(.87) 0.058	(.61) 0.041	(.32) 0.021	(0) 0	(0) 0	(.93) 0.062
7	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0
8	(.59) 0.039	(.95) 0.063	(1.19) 0.029	(1.44) 0.096	(1.25) 0.083	(.93) 0.062	(0) 0	(0) 0

( ) distance in miles
Travel time in hours

road locations are shown on Figure 3. Next it is necessary to calculate an appropriate unit cost for each proposed length. After the length of each link and the unit costs are found, the total cost can be determined and reduced to an average annual equivalent cost. The results are shown in Table 11.

TABLE 11

Average Annual Road Costs

Link j	Length miles	Unit Cost $/mile	Total Cost	Annual Cost 50 Yrs. @ 6%
1	0.13	300,000	39,000	2,400
2	0.34	280,000	45,200	6,000
3	0.35	200,000	70,000	4,400
4	0.28	200,000	56,000	3,600
5	0.08	350,000	28,000	1,800
6	0.21	300,000	63,000	3,900

IV. RESULTS AND DISCUSSION OF RESULTS

The output from this technique solves for the unknown values of $ACTS_{ij}$, the amount of activity i that should be allocated to zone j. Several solutions are printed out in tabular form along with the total annual cost, the annual establishment cost, the annual road cost, and the annual travel cost for each solution obtained. By inputting the data described above into the computer program, several near optimal solutions are obtained and the one which has the minimum annual cost is considered the optimal solution. However, as discussed previously, the answer obtained cannot immediately be considered the global optimal solution. For the data formulated and a value of time of $2.00, the optimal solution obtained is given in Table 12. It should be noted that the allocation includes only integer values, the technique will not allocate fractional parts of any activity. The annual cost associated with the allocations given in Table 12 is shown in Table 13.

The result of the technique as applied to recreational planning appears to be promising, although it does appear to have some weak points in its present stage of development. This can be seen by the allocation where swimming is located a distance from picnicking and camping. This problem may be overcome by adding additional constants to control the separation distance between activities. However, before the basic technique is changed, it should be applied to a real world situation. The data used in this research were computed by the author and may not be as reliable or accurate as necessary.

TABLE 12

The Minimum Cost Solution
for Placing Activity i in Zone j

Activity	Zone 1	2	3	4	5	6
1. Picnicking	5	11	0	0	0	0
2. Camping	0	16	0	1	0	0
3. Swimming	0	0	0	3	0	0
4. Boating	0	1	0	0	0	0
5. Sightseeing	0	0	0	0	0	0
6. Vacant land	13	0	18	14	9	10
7. Gate	0	0	0	0	0	0

TABLE 13

Cost of Optimal Solution

Establishment Cost		$14,810.00
Road Cost		12,000.00
Travel Cost		12,635.09
	Total	$39,445.09

Because the technique does not necessarily reach a global optimum, several initial solutions should be tried. The second solution tried in this research resulted in an allocation which appears to be better than the one described above. The second solution resulted in an allocation with all activities placed in zones 2 and 3. Zone 2 contained 12 acres of picnicking and 16 acres of camping; and zone 3 contained 4 acres of picnicking, 3 acres of swimming, and 1 acre for boating. The total cost was reduced by $1,560 with the total annual construction cost equal to $25,450. Thereby reducing the construction cost by $1,360, although these figures do not appear to be significant, the savings could be significant for projects having total construction costs in the millions of dollars.

To test the developed computer program, a final solution was used as an initial for input, with the results obtained being the same. The allocation of activities, the total cost, and the component costs did not change.

Also, to determine the total savings that could result from the use of this technique, a solution was obtained where the cost was maximized instead of minimized. The resulting annual establishment and road costs equaled $35,070 or an increase in annual cost of $8,260. Although this example may not approach the extreme condition, it does show the validity of the procedures.

It can be seen that the optimization or minimization techniques does not replace the planner, but does give him a set of solutions from which to choose. From his own personal experiences or because of factors which cannot be put into a computer, the planner may decide that the solution with the minimum cost may not be the best overall plan. In addition, the planner has the liberty to choose to what degree of accuracy his data must be collected and also may refine the model to suit his particular application. The accuracy of data collection is important, since it is usually not known initially how much data and to what degree of accuracy the data should be collected. By using rough estimates as initial data, the planner may determine what additional data is necessary from the results of the first solution. Sensitivity analysis may also be used to determine the degree of accuracy of the data collection and is described in the next section.

Sensitivity Analysis

A sensitivity analysis may be conducted to determine which input parameters are most critical in determining the solution and therefore require more careful estimation. It is based on the changes in behavior of the merit function due to small changes in the design or data variables.

In an attempt to illustrate the sensitivity of the objective function, four variables were changed. First the road costs were reduced by 50 percent and then increased by 10 percent, second, the establishment costs were reduced by 50 percent and increased by 10 percent, third, the value of time was reduced from $2.00 to $1.00 and then increased to $3.00 and fourth, the interest rate was increased from 6 percent to 8 percent and then to 10 percent. A summary of the results are shown in Table 14.

It can be seen that with a 10 percent increase in establishment costs or road costs the difference in total annual construction cost is very small. However, a decrease in establishment costs has a larger effect on the value of the objective functions and the construction costs than does a similar decrease in road costs. Thus, the planner may want to take a closer look at establishment costs to determine the validity of the estimate.

Although the purpose of this research is not to determine the appropriate value of the interest rate that should be used, the general effects can be shown. For the input data for the hypothetical reservoir chosen, an increase in the interest rate of 2 percent increases the annual construction costs about 35 percent. Thus the discount rate can have an enormous effect on project justification. However, the rate used is usually not left to the judgement of the planner.

The value of time can also have a noticeable effect on the total annual cost. As stated before, the travel cost is not usually considered as part of the total project cost, but should be taken into consideration during project planning. By increasing the travel cost, the resulting allocation places the activities closer together and thereby decreases the total travel within the reservoir area. But, at the same time the annual establishment cost and road cost are increased. Thus, the final decision is left to the planner and/or planning agency. Should travel be reduced, thereby allowing for more interactions between activities or should travel be sacrificed for a reduction in total construction cost?

TABLE 14

Sensitivity Analysis

	Item	Road Cost	Establishment Cost	Travel Cost	Total Cost
Inital Solution		12,000	14,810	12,635	39,445
Road Cost	Decreased 50%	6,000	14,810	12,635	33,444
	Increased 10%	11,110	16,710	12,721	40,541
Estab. Cost	Decreased 50%	8,400	8,200	9,715	26,315
	Increased 10%	11,700	16,065	12,057	39,822
Interest Rate	8%	10,820	25,360	10,656	46,836
	10%	17,400	19,210	13,080	49,690
Value of Time	$1.00	6,800	15,990	5,328	28,118
	$3.00	12,000	14,810	18,952	45,762

V. OTHER APPLICATIONS

There are several other ways this technique can be useful. For example, the planner is sometimes faced with a yes/no type of decision, such as might be the case of including a lodge as part of the total project or not including a lodge as part of the project. The problem may be broken down into two parts: (a) will the benefits accruing from the allocation outweigh the cost and if so, (b) where should the activity be located? Using the model as previously described, the cost of the allocations without the lodge is first determined. Next, a series of runs are made to determine the best location of the lodge facilities from a given number of pre-selected sites. An evaluation can be made of the costs and benefits of including the activity and the planner may make his own decision. Such evaluations are useful when dissident groups are opposed to alternatives to the initial plan. The alternatives may be evaluated and a comparison made with the original plan and a rational decision made according to the benefits that would accrue.

The application of this technique also allows for the consideration of historical, environmental and archaeological factors. If for one of the reasons given above or even for some other reason, it is desired that no activity i be placed in any particular zone j, the cost of allocation of any activity in the zone in question can be increased to such a value that that zone will be removed from competition. For instance, if zone 1 contained some historical characteristic that should not be destroyed or altered, zone 1 could be eliminated from competition by increasing the cost of placing each activity in that zone. To demonstrate this procedure, the cost per acre of allocating each activity in zone 1 was increased to an annual cost of $10,000. The resulting allocation removed all activity from zone 1 and increased the total costruction cost from $26,810 to $28,470, an increase in annual cost of $1,660. If some measure of benefit can be placed on the characteristic being preserved, the benefits should be enough to compensate for the additional annual cost of $1,660.

Also, it may in some instances be desirable that activities be allocated in increments of 2 acres instead of 1 acre increments. This can be accomplished by simply dividing the acres required and the acres available by 2 and adjust the cost accordingly. The same procedure can be applied if allocations are required in 1/2 acre increments. Other factors such as aesthetics, increased view, accessibility to water, and even, in some cases, reservoir drawdown can be taken into consideration. To accomplish this, the planner would have to develop a standard method of increasing or decreasing the unit cost per acre according to number of qualities the particular allocation has or does not have. For example, the operation of the hypothetical reservoir being used for this research may require periods of drawdown resulting in large mud flats in zone 4 and thus making it difficult for swimmers to reach the water. Whereas, in zone 3, the drawdown effect would not be as detrimental. Therefore, the planner may wish to decrease the cost of allocating swimming in zone 3 to take this into account.

The same procedure could apply to increased view. The planner may decide that campers would accrue more benefits if the camping facilities were arranged so that the reservoir could be seen from the camping area.

The topography in zone 2 may be such that the water cannot be seen. He may decide to decrease the cost of allocating camping to zone 4 for the sole reason that the view from zone 4 is better.

VI. CONCLUSIONS

It is of the opinion of the author that a technique such as TOPAZ can be a powerful aid to the planner of water based recreational facilities. The technique appears to generate allocation patterns very close to the global optimum with relatively small computational time on the IBM 360/65 computer.

As far as the application of the technique is concerned, it is apparent that the planner has at his disposal a method to test various input variables and determine the relative effect each would have on the overall final plan. By sensitivity analysis, the planner is able to determine the degree of accuracy to which the raw data should be collected, which is also a powerful aid to the planning profession, both in terms of time and money.

The use of the technique to handle non-quantifiable, or yes/no type, decisions seems to have some potentially useful outgrowth, especially at the present time when dissenting groups have put additional pressure on the planning profession. As mentioned before, the different alternatives can be presented and a rational decision of the best overall plan can be determined.

The application of the technique to the hypothetical reservoir used shows that travel and travel cost can and should be an important factor in the final allocation of activities. Even though the present procedure does include travel, it does not insure any degree of interaction between activities. The model does penalize the value of the objective function when the distance between activities becomes great, but there is no assurance that the trips will occur and the optimal use of the facilities will be obtained.

The application does show that the recreational planner has at his disposal a method to reach any degree of land use development he desires to obtain. By varying the input variables, he can obtain an optimal land use allocation for the particular reservoir under study. As far as the total cost of the recreational facilities is concerned, the applications did not produce any startling results, but it did provide some additional verifications of present thinking. That is, that the road construction is a major part of the total construction cost and plays an important part in the final allocation. This can be seen by observing the final allocation in the initial solution where no activity is allocated in zone 2 even though zone 2 has the lowest establishment cost for 3 of the 4 activities. This is due to the comparatively high road cost to provide access into zone 2.

VII. RECOMMENDATIONS FOR FURTHER RESEARCH

One of the most obvious recommendations for further research on the use of TOPAZ when applied to recreational planning is to apply the procedure to a real world situation. This would include the use of data that may, in some instances, be more accurate than that employed in this research. It also includes the utilization of more activities, more zones, and a higher annual visitation which would introduce more interactions and more travel.

If the results of the real world application are similar to the hypothetical one and travel shows a definite influence on the final allocation, then it is considered that the next step would be to obtain a better understanding of the travel pattern within a recreational complex. This would include the obtaining of raw data showing the inter-area movement and determination of this movement expressed as some function of the activities provided and the total annual visitation. Data should also be obtained so some type of travel model, such as the gravity model, could be used to insure a proper degree of interaction between activities. This would include the determination of production and attraction rates for each type of recreational activities. By knowing these rates, the total trips between activities can be determined and the maximum utilization of the recreational facilities can be obtained.

Also, the development of establishment cost estimates, depending upon the characteristics of the area in which the activities are to be placed, would be helpful in utilization of the technique. These rough estimates could be changed or improved depending upon the sensitivity analysis of the first run.

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APPENDIX

Input Variables

M	Number of zones
NACTS	Number of activities
NECTCM	Number of cost components
NLOOP	Number of iterations
AA(I)	Future acres of each activity I required
BB(J)	Acres of land available for development in each zone J
PERENT	Total annual visitation
UDPY	User days per year
VOT	Dollar value of time
ESTCST(I,J)	Establishment cost matrix or the cost of placing each activity I in each zone J
TT(J,K)	Travel time matrix or the travel time from some zone J to some other zone K
RCOST(J)	Road cost matrix or the cost of access to each zone
TROCPR(I)	Trip occurrence percentage or total visitation to each activity I expressed as a percentage of the total annual visitation
PERTRP(I,J)	Percent of trips going from some activity I to some other activity J
ACTS(I,J)	Number of acres of activity I in zone J

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OPTIMAL ALLOCATION OF RECREATIONAL
ACTIVITIES WITHIN A RESERVOIR AREA
UTILIZING TOPAZ

by

Roland W. Culpepper, Jr.

(ABSTRACT)

TOPAZ, which is the Technique for the Optimal Placement of Activities in Zones, was developed to provide the urban planner with a workable tool from which he could determine the best allocation of a set of activities to a set of zones and at the same time minimize cost. The main objective of this research was to determine if TOPAZ could be applied to reservoir recreational planning, and if so, the methodology necessary for its use.

An example problem which includes a hypothetical reservoir with six zones and four key recreational activities is posed for the testing of the technique. The four key recreational activities being studied are swimming, picnicking, camping and boating. The model which was developed includes three cost components which are the establishment cost, the road cost and the cost of travel.

It is shown that the technique can be a powerful aid to the planner of water based recreational facilities.

Not only does the model give the planner a series of near optimal allocations of activities, but by the use of the sensitivity analysis the degree of accuracy to which the data should be collected can be

determined. The model is also shown to be useful when applied to non-quantifiable type decisions.

The results and a discussion of the results are included along with a discussion of other possible applications of the technique as applied to recreational planning. The planner can refine the model to suit his own particular needs by modifying the data input and the associated constraint set.