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An Analysis of the Application of Club Good Models to Determine Carrying Capacity of National Parks

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The National Parks and Recreation Act of 1978 requires that park managers develop and implement a plan regarding visitor carrying capacity. In response, econometricians have developed models that may be helpful to park management in regards to meeting this goal. The focus of this paper is to highlight some of the earlier work done by Buchanan (1965) and Ng (1973) in regards to modeling club goods and then to examine more recent attempts by Turner (2000) and Prato (2001) in applying these models to help determine carrying capacity of national parks. Turner (2000) and Prato's (2001) models will then be evaluated in regards to potential implementation problems.

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I. Introduction

The US National Park Service Organic Act of 1916 required that national parks must be managed such that scenery, natural and historic objects, and wildlife are conserved. This act also mandated that the park managers should provide recreational opportunity for visitors and non-impairment of resources (Prato, 2001). These two important goals have been difficult to balance as national parks have experienced increased visitors and thus higher levels of congestion. Subsequently, the National Parks and Recreation Act of 1978 required that park managers develop a plan to identify and implement such a plan to address visitor carrying capacity (Prato, 2001).

II. Public v. Private Goods

Economists have struggled to find a satisfactory treatment for those goods which do not fall neatly into one of the two categories of public (collective-consumption) and private (individual-consumption) goods. While it may be more satisfying (in terms of analysis) to distinguish between these two types of goods, in reality, a number of goods fall between these two polar opposites.

Weisbrod (1964) points out that there is a significant number of private goods that have characteristics of public goods. Because the frequency of purchase of quasi-public goods is uncertain and the associated costs of expanding production once services have been reduced, Weisbrod (1964) felt that social welfare is benefited by subsidizing the production of these goods.

Using Sequoia National Park, Weisbrod (1964) first made the assumption that even with admission fees it would be impossible to cover total costs. This is due to the lack of traditional external consumption or production factors. Another hindrance is that the commodity is not storable and therefore cannot be purchased and then used at a later date. With total costs being greater than total revenue, Marshallian analysis would dictate that the park be closed and that alternative uses for the park's resources should be found. Of course, this is only considering allocative efficiency and ignores social welfare factors. Ignored in this case are the people who are willing to pay for the option to purchase this commodity (visit the park) in the future. This "option value" will have little influence in the private market, however, because there is no practical mechanism for calculating user fees. Furthermore, if revenue is insufficient and the park is closed, the option demand for future park usage will not be taken into account (Weisbrod, 1964, 473).

Weisbrod (1964) then considers the case where user fees are adequate to cover total costs. This means that "the option demand of persons who [are] not current consumers would be satisfied at zero marginal cost (Weisbrod, 1964, 473)." That is to say, so long as the park is in operation, the option exists as a pure public good. A pure public good is defined as a good that can be consumed simultaneously without detracting from the consumption opportunities for others. This means that the park can then be viewed as having an external economy with two outputs: service to users and stand-by services to non-users.

The latter statement is difficult to quantify due to the fact that some of the "stand-by" users will not become actual users. Aside from considering the frequency of purchase, another consideration is the high costs of expansion or recommencement of production in a short time frame. This, in fact, may be an impossible demand. Consider the case where a large section of trees has been cut down. In Sequoia National Forest, it would take centuries for the forest area to be restored. This means that the occasional user would find it difficult, if not impossible, to purchase the good. In this case, the costs associated with recommencement of production are too high (Weisbrod, 1964).

In their book The Theory of Externalities, Public Goods and Club Goods, Richard Cornes and Todd Sanders (1996) outline four distinct characteristics of club goods. The first characteristic is that an increase in membership size, and thus increased congestion, will lead to an increase in both costs and benefits. The additional costs are a result of the now increased congestion and the benefits are the result of cost reductions that occur due to the sharing of membership expenses. This is in contrast to public goods, where costs associated with increased membership will be zero. Second, club goods will have a finite membership. Third, for club goods, nonmembers have the choice of joining another club that offers the same club good, or they may choose not to join a club. Fourth, toll fees require that there exist some exclusion mechanism that prevents nonmembers from using the club good.

III. General Theory of Clubs

Buchanan (1965) developed a general theory of clubs in order to bridge the gap between purely public and purely private goods. In the case of pure private goods, consumption by one individual automatically reduces the consumption level of another individual. For pure public goods, however, there is non-rivalry in consumption of goods and so goods may be used simultaneously with no effect on competing consumers. While pure public goods can serve an infinite number of consumers and pure private goods have only an individual consumer, the typical public good usually falls somewhere between pure public and private goods and will have a finite number of consumers greater than one. The central question then becomes, what is the optimal number of consumers or the membership margin, otherwise defined as "the size of the most desirable cost and consumption sharing arrangement (Buchanan, 1965, 2)."

Using neo-classical models that consider the case of pure private consumption only, the individual utility function is written,

(1) $U=U(X_1,X_2,\ldots,X_n)$

where each X represents the quantities of pure private goods available to each individual during a specified time period. This is then extended to include both pure public and private goods,

(2) $U=U(X_1,X_2,\ldots,X_n,X_{n+1},X_{n+2},\ldots,X_{n+m})$

with $X_{n+1},X_{n+2},\ldots,X_{n+m}$ representing the quantity of pure public goods available to each individual during a specified time period (Buchanan 1965).

With a non-pure good, however, an individual's utility is a function of "the number of other persons with whom he must share its benefits (Buchanan, 1965, 3)." Sharing here means that the individual consumes a reduced quantity of the good. Consider a group of *i* people sharing one hair cut per month. This means that each person would receive 1/*i*th haircut per month. "Given any quantity of final good, as defined in terms of the physical units of some standard quality, the utility that the individual receives from this quantity will be related functionally to the number of others with whom he shares (Buchanan, 1965, 3)."

The number of individuals who share the good, or club size, is disregarded in the study of pure private goods because the optimal level is unity. In the case of club goods, however, the club size *N* will need to be included for each good. The "club size variable, *N*, therefore measures the number of persons who are to join in the consumption-utilization arrangements for good *X* over the relevant time period (Buchanan, 1965, 4)." This produces the rewritten utility function,

(3) $U=U((X_1,N_1),(X_2,N_2),\ldots,(X_{n+m},N_{n+m}))$

From here, it is possible to derive the marginal conditions for Pareto optimality. First, define the production function as,

(4) $F=F'((X_1,N_1),(X_2,N_2),\ldots,(X_{n+m},N_{n+m}))$

The club-size is a necessary part of this function because a relationship exists between club-size and cost and club-size and quantity purchased. For example, a larger club-size will usually result in lower collected fees. As a negative externality, however, this may result in reduced quantity of service. A large golf club, for example, may mean it is more difficult to schedule a tee time (Buchanan, 1965).

The production function makes it possible to derive equations for the necessary marginal conditions for Pareto optimality with respect to consumption for two goods X_j and X_r. Because the marginal rate of substitution for consumption is equal to the marginal rate of substitution for production,

(5) $u_j/u_r=f_j/f_r$

and by incorporating club-size, this can be written as,

(6) $u_{Nj}/u_r = f_{Nj}/f_r$

This relationship says that equilibrium occurs when the marginal benefits of adding a new member to the club are equal to the marginal cost of adding a member to the club. We can then combine (5) and (6) to show,

(7) $u_j/f_j = u_r/f_r = u_N/f_N$

When (7) is satisfied, the individual will have an optimal quantity of X_j and will be “optimally” sharing this good over a finite group of individuals (Buchanan, 1965).

IV. Ng Model

Beginning with Buchanan’s equation (6), Ng (1973) believes that the “conditions…obtained are the equilibrium conditions for an individual, given his market opportunities and assuming he can choose his preferred N_j. [Therefore], for Pareto optimality, we have to maximize the utility of an individual, subject to the constraints that the level of utility of each other individual is held constant and that society’s production possibilities are given (Ng, 1973, 291).”

Let there be s individuals, m collective goods, and (n-m) private goods modeled by the following utility function for each *i*th individual

(N!) $U^i = U^i(X_1, N_1, D_{i1}, \ldots X_m, N_m, D_{im,} X^i_{m+1}, \ldots X^i_n)$

where X*j* and N*j* represent the quantity of and the number of individuals consuming the *j*th collective good, X^i_j is the amount of the *j*th private good consumed by the *i*th individual, and D*ij*=1 if individual *i* belongs to club *j* and 0 if not. Divisibility in the quantity of all goods and continuousness of N*j* is also assumed (Ng, 1973).

The production function can then be written

(N2) $F(X_1,\ldots,X_m,\sum_{i=1}^{s} X_n^i) = 0$

In order to derive the necessary conditions for Pareto optimality, U_i must be maximized subject to the constraint $U^i = \overline{U}^i \ (i = 2,\ldots,s)$. Therefore, the Lagrangian function can be written,

(N3) $L = U^1 + \sum_{i=2}^{s} \lambda^i (U^i - \overline{U}^i) - \theta F$

By taking the partial derivatives respective to L the following equation are obtained:

(N4) $\sum_{i=1}^{s} \lambda^i U_{Xj}^i = \theta F \qquad (j = 1,\ldots,m)$

(N5) $\lambda^i U_{Xj}^i = \theta F \qquad (j = m+1,\ldots,n; i = 1,\ldots,s)$

(N6) $\sum_{i=1}^{s} \lambda^i U_{Xj}^i = 0 \qquad (j = 1,\ldots,m)$

Next, by combining equations N4, N5, and N6 and using X_n as a numeraire,

(N7) $\sum_{i=1}^{s} U_{Xj}^i \big/ U_{Xn}^i = F_{Xj} \big/ F_{Xn} \qquad (j = 1,\ldots,m)$

(N8) $\sum_{i=1}^{s} U_{Xj}^i \big/ U_{Xn}^i = 0 \qquad (j = 1,\ldots,m)$

Utilizing the fact that $U_{Xj}^i = U_{Nj}^i = 0$ for individuals not consuming Xj, equation N7 can be written as

(N9) $\sum_{i=1}^{Nj} U_{Xj}^i \big/ U_{Xn}^i = F_{Xj} \big/ F_{Xn} \qquad (j = 1,\ldots,m)$

(N9’) $\sum_{i \in sj} U_{Xj}^i \big/ U_{Xn}^i = F_{Xj} \big/ F_{Xn} \qquad (j = 1,\ldots,m)$

However, due to the fact that N_j is a discrete variable, it is more appropriate to use

(N10) $\Delta U^i_j + \sum_{k \neq i} U^i_{Xn} (U^k_{Nj} / U^k_{Xn}) \geq 0$ if $i \in S_i$; ≤ 0 if $i \notin S_i$

which can be written in terms of the marginal rates of substitution,

(N10') $\int_0^{\overline{X_j}} (U^i_{Xj} / U^i_{Xn}) dX_j + \sum_{k \neq i} U^k_{Xj} / U^k_{Nn} \geq 0$ if $i \in S_j$; $\leq$ if $i \notin S_i$

"This says that, for each collective good, any individual in the club must derive a total benefit from the consumption of that good in excess of (or at least equal to) the aggregate marginal disutility imposed on all other consumers in the club (Ng, 1973, 293)." The reverse is also true for individuals not in the club. Equation N9' says that aggregate marginal valuation equals the marginal cost (this is the Samuelson condition with the exception that the set of consumers does not need to equal the set of individuals in society, or $N_j \neq s$. This differs from Buchanan's analysis in that Buchanan's equilibrium equation (6) is no longer necessary for Pareto optimality. This is due to the fact that "N_j enters into the utility function of a number of consumers simultaneously, and each consumer cannot vary at N_j at will. Hence the relevant condition for each N_j is the aggregate marginal valuation rather than the individual marginal valuation (Ng, 1973, 293)."

V. Turner Model

Visitors making use of national parks enjoy a variety of activities, including: hiking, biking, fishing, boating, swimming, cross-country skiing, horseback riding, and in some parks snowmobiling. As the number of people making use of park services has risen, park congestion has increased, diminishing user benefits. This congestion creates a situation where national parks are not purely public goods, but rather are club goods.

Using Glacier National Park, Turner (2000) developed a hypothetical model for managing multiple activities at a national park. In particular, Turner's model considers entrance fees and other user fees (Turner, 2000).

Turner's analysis employs a variable-utilization mixed-club model. This method was chosen because the club (national parks) consists of a group of members (park visitors) who have diverse tastes and therefore will utilize the club differently. In this case, the "club is a single multiproduct club with unrestricted membership; the park is unique, it offers more than one activity and admission to the park is open to all (though there may be an entrance fee or other toll that some individuals choose not to pay) (Turner, 2000, 475)." In order to simplify the model, visitors are restricted to two activities, or two goods (Turner, 2000).

Turner defines individual utility as a function of a numeraire good y, recreation V, and wilderness W. Since wilderness is a public good, everyone consumes an equal amount. Therefore, an individual's utility can be written as $U=U(y,V,W)$. Recreational benefits can be defined by the number of visits v and the index of enjoyment Φ. Therefore, $V=v\Phi$. Now, let a_1 and a_2 be variables for the amount of time spent engaged in each of the two activities. Next, let q_j represent the quality of the activity such that for each individual the quality-adjusted amount of activity j engaged in for each individual is represented by $\alpha_j=a_jq_j$. Therefore, $\Phi=\Phi(\alpha_1,\alpha_2)$ represents the enjoyment per visit derived for each individual (Turner, 2000).

Congestion, park size, and wilderness will affect visitor enjoyment, although to what degree depends upon visitor preferences. Therefore, quality decreases by γ_j for each additional unit of congestion and quality increases in relation to the size of the park, *Z*, and wilderness area, *W*. None the less, it should be recognized that an increase in wilderness area can increase congestion. Thus, quality of activity *j* by for each individual is given by $q(\gamma_j, Z, W)$ (Turner, 2000).

Total congestion is a function of the total amount of each activity. Therefore, if $A_1 = \Sigma va_1$ and $A_2 = \Sigma va_2$, then $\gamma_j(A_1, A_2, Z, W)$. *Z* and *W* are included because the larger the size of the park or the larger the wilderness area, the less likely there will be congestion cross-over effects that interfere with individual enjoyment of the park. Similarly, wilderness can be defined as a function the two activities and park size, or $W = W(A_1, A_2, Z)$ (Turner, 2000).

Efficiency Conditions

The socially efficient allocation of resources can then by found by maximizing the Benthamite social welfare function ΣU with respect to the resource constraint $E \geq \Sigma y + \Sigma \tau v + C(Z, A_1, A_2)$ where E is society's endowment of the numeraire, τ is each individual's travel cost, and $C(\cdot)$ is the cost function for the park. Therefore, the Lagrangian for the constrained optimization problem is:

(T1) $L = \Sigma U(y, V, W) + \mu(E - \Sigma y + \Sigma \tau v + C(Z, A_1, A_2))$

Where $V = v\Phi(a_1 q_1(\gamma_1(A_1, A_2, Z, W), Z, W), a_2 q_2(\gamma_2(A_1, A_2, Z, W), Z, W))$; $A_j = \Sigma va_j$ for j=1,2; $W = W(A_1, A_2, Z)$ and μ is the Lagrangian multiplier. The park manager/planner then chooses y, v, a_1, and a_2 for each individual and also chooses Z. First order conditions can then be manipulated to yield,

(T2)
$$MRS_{Vy}\phi = \tau + (C_{A_1} + \Gamma_1 \frac{\partial\gamma_1}{\partial A_1} + \Gamma_2 \frac{\partial\gamma_2}{\partial A_1})a_1 + (C_{A_2} + \Gamma_1 \frac{\partial\gamma_1}{\partial A_2} + \Gamma_2 \frac{\partial\gamma_2}{\partial A_2})a_2 - (P_W + \varepsilon_W - \Gamma_1 \frac{\partial\gamma_1}{\partial W} - \Gamma_2 \frac{\partial\gamma_2}{\partial W})(W_{A_1} a_1 + W_{A_2} a_2) \quad \forall i$$

(T3)
$$MRS_{Vy}\phi q_1 = C_{A_1} + \Gamma_1 \frac{\partial\gamma_1}{\partial A_1} + \Gamma_2 \frac{\partial\gamma_2}{\partial A_1})a_1 - (P_W + \varepsilon_W - \Gamma_1 \frac{\partial\gamma_1}{\partial W} - \Gamma_2 \frac{\partial\gamma_2}{\partial W})(W_{A_1} a_1) \quad \forall i$$

(T4)
$$MRS_{Vy}\phi q_2 = C_{A_2} + \Gamma_1 \frac{\partial\gamma_1}{\partial A_2} + \Gamma_2 \frac{\partial\gamma_2}{\partial A_2} - (P_W + \varepsilon_W - \Gamma_1 \frac{\partial\gamma_1}{\partial W} - \Gamma_2 \frac{\partial\gamma_2}{\partial W})(W_{A_2} a_2) \quad \forall i$$

(T5)
$$\varepsilon_Z - \Gamma_1 \frac{\partial\gamma_1}{\partial Z} + \Gamma_2 \frac{\partial\gamma_2}{\partial Z} - (P_W + \varepsilon_W - \Gamma_1 \frac{\partial\gamma_1}{\partial W} - \Gamma_2 \frac{\partial\gamma_2}{\partial W})(W_Z) = C_Z$$

where MRS represents the marginal rate of substitution;

(T6)
$$\Gamma_j = -\sum MRS_{Vy} v \Phi_{\alpha_j} a_j \frac{\partial q_j}{\partial\gamma_j} \qquad j = 1,2$$

which represents the aggregate costs to visitors caused by marginal increases in congestion due to activities 1 and 2; $P_W=\Sigma_j MRS_{Wy}$ is a Samuelson summation of marginal rates of substitution. P_W measures the aggregate benefit to society of an increase in W. ε_Z and ε_W show the effect of park size and wilderness on visitor enjoyment. Expression T5 is the provisional condition whereby the park's size should by enlarged until marginal social benefit is greater than marginal social cost. Having a larger park is beneficial because it decreases congestion, increases wilderness, and thus leads to potentially greater rates of visitor enjoyment. Expressions T2 thru T4, represent toll (user fee) conditions (Turner, 2000).

Utility Maximization for Individuals

"An individual maximizes utility subject to the constraint that consumption of the numeraire plus the cost of visitation, which includes travel costs as well as a park entrance fee F and tolls t for each activity, must not exceed the individual's endowment of the numeraire E (Turner, 2000, 477)." The Lagrangian can be written,

(T7) $L=U(y,v\Phi(a_1q_1,a_2q_2),W+\lambda(E-y-(\tau+F-t_1a_1-t_2a_2)v)$

where variables y, v, a_1, and a_2 are choice variables and λ is the Lagrange multiplier. Assuming people do not consider congestion a deterrent to visiting the park yields a set of first order conditions which can be manipulated to give,

(T8) $\mathrm{MRS}_{Vy}= \tau+F+t_1a_1+t_2a_2$

(T9) $\mathrm{MRS}_{Vy}\Phi_{\alpha_1} q_1=t_1$ and

(T10) $\mathrm{MRS}_{Vy}\Phi_{\alpha_2} q_2=t_2$

Interpretation of Toll Conditions

Using the individual's optimization conditions T9 and T10, T3 and T4 implies that the planner can influence individuals to make socially efficient choices by implementing a toll equal to

(T11) $$t_j = C_{A_j} + \Gamma_1 \frac{\partial\gamma_1}{\partial A_j} + \Gamma_2 \frac{\partial\gamma_2}{\partial A_{j1}})a_1 - (P_W + \varepsilon_W - \Gamma_1 \frac{\partial\gamma_1}{\partial W} - \Gamma_2 \frac{\partial\gamma_2}{\partial W})(W_{A_j} a_1) \quad \forall j$$

where the first term is the partial derivative of the cost function with regard to each activity, the second and third terms represent the increased tolls in response to an increase in congestion due to increased consumers for activities 1 and 2, and the last term represents the increase in tolls as a result of diminishing wilderness as a result of increased congestion. While the toll for each of the two activities should be different, each individual should pay the same toll. Some individuals may pay more because they consume a greater amount (Turner, 2000).

These tolls should help to internalize two types of externalities. First, as congestion increases, tolls will increase. Second, assuming the visitor activities reduce wilderness levels, this will raise tolls. Efficient activity tolls will mean that the resulting efficient entrance fee, *F*, is zero (Turner, 2000).

VI. Prato Model

Conventional definitions of carrying capacity were defined by the "number of visitors an area can sustain without degrading natural resources and visitor experiences (Prato, 2001, 322)." New definitions of carrying capacity, however, define carrying capacity as the "acceptability of natural resources and human impacts as measured by selected biophysical resource and social conditions, rather than the number of visitors (Prato, 2001, 321)." And while much progress has been made in determining carrying capacity, much of the previous work has been non-quanitative, thus making it difficult for park managers to provide quantitative proof that their park is meeting established standards for biophysical and social carrying capacity (Prato, 2001).

Prato's model consists of an *ex post* adaptive ecosystem management (AEM) model and the *ex ante* multiple attribute scoring test of capacity (MASTEC) method. The AEM model "determines whether the current state of an ecosystem is compliant with biophysical and social carrying capacities…[by incorporating] adaptive management and ecosystem management principles…[that are] implemented using Bayes' rule (Prato, 2001, 322)." The MASTEC method "identifies the best management action for bringing an incompliant ecosystem into compliance…[by utilizing] a stochastic multiple attribute programming model (Prato, 2001, 322)."

AEM Model

To begin, assume each unit of the National Park Service falls into one of four categories after evaluating the unit's compliance with policy concerning caring capacity: M_1, M_2, M_3, or M_4, where M_1 is highly compliant, M_2 is moderately compliant, M_3 moderately incompliant, and M_4 is highly incompliant. The prior probabilities are then $p(M_1)$, $p(M_2)$, $p(M_3)$, and $p(M_4)$ which sum to one. Next, let R_1, R_2, R_3, and R_4 represent the characteristics of a unit's resource/social conditions. For example, let the percentage of native species and suitable endangered species habitats represent the resource attribute and let the level of congestion and wait-time for public transportation in the park be the social attribute. R_1 in this case represents a significant loss in native species, highly degraded endangered species habitats, high levels of congestion, and very long wait-times for public transportation. R_2 units will have moderate loss in native species, moderately degraded endangered species habitats, moderately high levels of congestion, and long wait-times for public transportation. R_3 units will have most native species present, good habitat areas for endangered species, low congestion, and short wait-times for public transportation. R_4 units have abundant native species, excellent habitats for endangered species, very little congestion, and very short wait-times for public transportation (Prato, 2001).

The AEM model uses Bayes' rule in order to minimize errors due to park managers misidentifying the unit's carrying capacity. There are two types of errors that commonly occur. The first occurs when the park manager identifies a unit as being compliant with carrying capacity conditions when it is not. The second occurs when the park manager decides the unit is incompliant with carrying capacity conditions because of resource/social conditions when the park is actually compliant with carrying capacity conditions (Prato, 2001).

Using the AEM model, (M_i R_q) is the outcome of a unit's carrying capacity and resource/social condition where i=1,2,…I and q=1,2,…Q, thus resulting in IQ possible outcomes. "Prior probabilities of resource social condition R_q (outcomes are mutually exclusive) is,

(P1) $p(R_q)=p(M_1,R_q)+\ldots+p(M_I\,R_q)$

where $p(M_i\,R_q)$ is the joint probability of (M_i R_q) (Prato, 2001, 324)." Bayes' rule defines the "probability that the ecosystem is in state M, given the condition R_q, is:

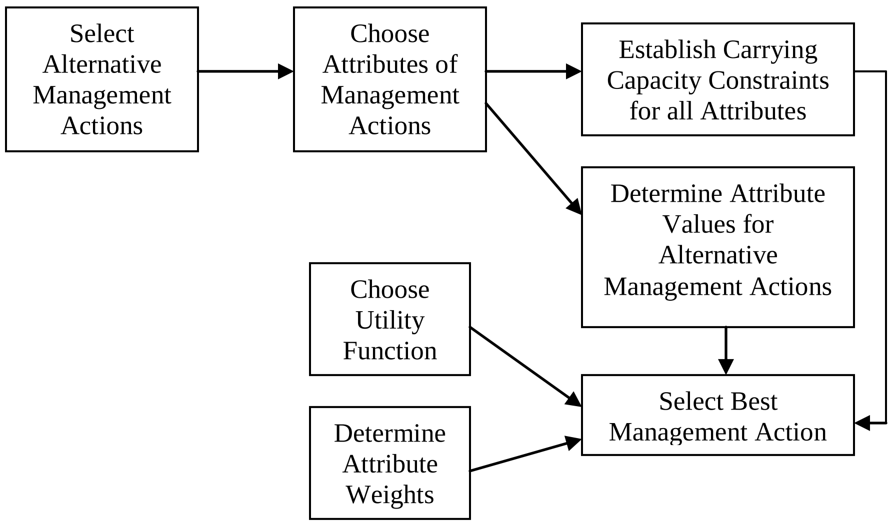
(P2) $p(M_i|R_q)=p(M_i\,R_q)/p(R_q)=[p(R_q|M_i)p(M_i)]/[\Sigma p(R_q|M_i)p(M_i)]$

where $p(M_i|R_q)$ is the posterior probability, $p(R_q|M_i)$ is the likelihood function for R_q, $p(M_i)$ is the prior probability of M_i, and $\Sigma p(R_q|M_i)p(M_i)$ is the expected value of the likelihood function (Prato, 2001, 324)."

MASTEC Method

If the AEM model indicates that the unit is most likely R_3 or R_4, than there is no need for the park manager to makes changes. However, if the AEM model indicates that the unit is R_1 or R_2 the MASTEC method can be used to achieve a compliant ecosystem state. "The MASTEC method is an *ex ante* procedure…[that helps] the manager select the best management action for achieving compliance with carrying capacities (Prato, 2001, 324)." The MASTEC method integrates the Limits of Acceptable Change and Visitor Impact Management carrying capacity methods. The Limits of Acceptable Change method "requires a manager to identify where and to what extent, changes in key biophysical and social processes are appropriate and acceptable, and to select a management action that is most likely to achieve conformance between observed conditions and established standards (Prato, 2001, 324) ." A schematic of the MASTEC method is given below in Figure 1 (Prato, 2001, 325),

Figure 1



The best result for management will maximize the expected utility function "$E[U(\mathbf{z})]$ subject to the constraint $\mathbf{z}=\mathbf{a}+\mathbf{e}$ where **z** is a stochastic vector of attributes provided by a management action, **a** is the deterministic component of **z**, which gives the expected amounts of all attributes provided by the management action, and **e** is the stochastic component of **z**, where $E(\mathbf{e})=0$ (Prato, 2001, 331)."

By solving the following chance-constrained mathematical programming problem, management will find the best solution:

Maximize $E[U(\mathbf{z*})]=$

$$E[U(\mathbf{a*}+\mathbf{e*})] \text{ subject to:} \Pr\{b_j^{*} \geq b_j^{**}\} \geq 1-\alpha_j \text{ for } j=1,\ldots,J, \text{ and}$$

$$\Pr\{s_k^{*} \geq s_k^{**}\} \geq 1-\beta_k \text{ for } k=1,\ldots,K$$

where * indicates normalized attribute values. This is done to reduce management ranking bias created by differences in measurement units and to convert negative attributes (attributes that are negatively related to utility) to positive attributes. Thus, rather than less of an attribute increasing utility, more of an attribute increases utility. The normalized attribute falls between [0,1]. The biophysical attributes b_j^* are at least as great as the biophysical standard b_j^{**} with reliability 1-α_j where 0< α_j <1 for all j biophysical attributes. Similarly, social attributes s_k^* are at least as great as the social standards s_k^{**} with reliability 1-β_k where 0< β_k <1 for all K social attributes (Prato, 2001).

Specifying that $E[U(\mathbf{z*})]$ is additive, meaning $E[U(\mathbf{z*})] = E[U_1(z_1^*)] + ... + E[U_V(z_{J+K}^*)]$, implies that the marginal utilities of each of the attributes are independent. Assuming the manager is risk neutral, the expected utility function is, $E[U(\mathbf{z*})] = \sum_{j=1}^{J} w_j b_{jv}^* + \sum_{k=1}^{K} w_k s_{kv}^*$ where w_j and w_k are the weights for the j_{th} biophysical attribute and the k_{th} social attribute, 0< w_j <1, 0< w_k <1, and $\sum_{j=1}^{J} w_j + \sum_{k=1}^{K} w_k = 1$. If the manager has constant risk aversion, then $E[U(\mathbf{z*})] = \sum_{j=1}^{J} w_j [a_j - c_j \sigma_j^2] + \sum_{k=1}^{K} w_k [a_k - c_k \sigma_k^2]$; and if the manager has variable risk aversion and the utility subfunctions, Ui(z_i^*), then $E[U(\mathbf{z*})] = \sum_{j=1}^{J} w_j [U(a_j) - c_j \sigma_j^2] + \sum_{k=1}^{K} w_k [U(a_k) - c_k \sigma_k^2]$ with expected values a_j and a_k, variances σ_j^2 and σ_k^2, and positive scaling constants c_j and c_k (Prato, 2001).

Using a multiple attribute decision-making framework to implement the MASTEC method has the advantage of allowing more complex information concerning management decisions to be collapsed into a single number, it permits stakeholders with different attributes and/or values to rank and select management actions, it allows managers to identify the best method for complying with carrying capacity standards, and allows managers to evaluate the sensitivity of a management action to changes in attribute weights and values (Prato, 2001).

VII. Analysis and Evaluation of the Four Models

The initial framework provided by Buchanan has served as a benchmark/point of departure for each of the subsequent models. Ng's model is a modification of Buchanan's that utilizes aggregate consumer marginal valuation rather than individual consumer marginal valuation. Turner makes the choice to rewrite Buchanon's utility function in terms of a Benthamite social welfare function using a numeraire good, recreation, and wilderness area. Turner then rewrites the constraint in terms of society's valuation of the numeraire, travel costs, and the cost function of the park. In contrast, while the previously mentioned authors make use of the Lagrange method to maximize utility subject to a constraint, Prato takes a different route by employing the more technology based MASTEC method.

While Buchanan's and Ng's models help to formulate a model for general club goods, Turner and Prato's models specifically focus on applications concerning national parks. Because these models have yet to be implemented it is important that the models are evaluated and their weaknesses addressed.

Turner

Turner's (2000) model has several implementation problems. First, Turner's model uses ε_Z and ε_W to measure the impact of wilderness area and park size on visitor enjoyment. The potential problem with this is that both of these measures are inelastic. A park manager typically does not have the option of expanding the park when congestion levels are high. Nor does the park manager have the ability to expand the number of trees in a short time frame. This was one of the original arguments given by Weisbrod (1964) concerning the difficulty in storing or quickly replacing lost resources.

Data collection is particularly difficult in regards to using Turner's (2000) model to estimate carrying capacity. Currently, the appropriate data are not being collected to use this model. Turner's model requires the collection of data concerning the levels of congestion for various park activities and wilderness levels. Data also needs to be collected regarding park costs, visitor enjoyment, and public valuation of park services. Further difficulties exist in regard to formulating an effective survey, which is often a difficult and costly task that can result in biased conclusions.

Prato

While Prato's (2001) model may be the most difficult to implement, it may also prove to be the most useful. The most difficult task is the development of a spatial decision support tool. The development of this tool would provide numerous benefits to park management. First, it would make it easier to acquire and analyze technical information and public input. Second, the public would become more informed about the consequences of management decisions. The development of this tool would "enhance the manager's and public's understanding of how different attribute weights, attribute standards and reliability levels for achieving standards influence the selection of the best management action (Prato 2001, 329)." The development of this tool would also provide an analytic method for determining park managers' decisions. Finally, this tool would also help to alleviate conflict and create a database that would be useful for soliciting other funding opportunities.

The aforementioned benefits of Prato's model not withstanding, major impediments to implementing Prato's (2001) model include budgetary restrictions, a lack of technical expertise, high turnover of park management, and the long time-frame required to implement the AEM model, although some of the budgetary problems may be overcome by soliciting grant money.

VIII. Concluding Remarks

A sizable weakness of each of the models is the assumption that it is possible to exclude individuals who are not able and/or willing to be a part of the club. This includes both the direct violations as a result of visitors subverting park rules by making use of the park's services without paying a fee and more indirect violations. For example, non-users benefit from the maintenance of national park areas regardless of whether they choose to make use of the park. Some of these benefits include cleaner air, higher property values, scenic vistas, and preservation of wildlife. So long as the possibility exists for park users to make use of park services without paying the associated fees, there will be a percentage of consumers who will take advantage of the situation. This problem is further compounded by the difficulty and expense incurred in monitoring and fining these "free riders."

The ability to identify carrying capacity thresholds is also a difficult task for park managers. An individual's perception of environmental "damage" is often a subjective measure and therefore makes identifying a threshold level of damage extremely difficult. Some would measure this threshold as the point where damage becomes "noticeable" to consumers. At this point, demand for the good falls sharply and so the manager might see carrying capacity as a function of the number of visitors. This is not necessarily a consistent value, however, due to the fact that increased education and better management may lead to increased carrying capacity for the park (Davis, 2001).

Another concern is the transformation of national parks into a kind of "amusement park." If activities fees are used, how will this change the way the park looks? How will it change consumers' experiences? Do we charge hikers for each mile walked or do we restrict activity fees to activities such as tours, boating, etc.? These are all issues that would need to be addressed by the park manager if user fees were implemented.

Finally, any model incorporating a toll or user fee creates an ethical dilemma regarding the exclusion of the poor from public property. When one considers that there are few places for low-income families to enjoy recreational activities, some would argue that charging fees potentially excludes low-income families from a public good. Additionally, national parks are already subsidized by federal dollars that are the result of taxation. This means that some individuals may be paying for a good they are unable to use. This also raises a question regarding whether individual consumers of parks or all individuals who pay taxes should be responsible for maintaining park facilities.

Ultimately, a decision will need to be made in regard to the implementation of user fees; is the goal to reduce subsidization, reduce congestion, or both?

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