# THE ECONOMICS OF MANAGING CONGESTION: WITH SPECIAL REFERENCE TO BACKCOUNTRY RECREATION

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# THE ECONOMICS OF MANAGING CONGESTION: WITH SPECIAL REFERENCE TO BACKCOUNTRY RECREATION

**by G.N. Kerr**

The management of congestible recreation resources has been based largely on the concept of satisfaction. This concept is poorly defined and often does not reflect objectives for management of recreation resources. One way of addressing these problems is to define and use measurable objectives for management of recreation resources. One such objective is economic efficiency.

The concept of efficiency is defined and economic theory developed to identify: efficient allocations of congestible resources, the efficient capacities of resources under different allocation mechanisms, and the efficiency costs of use of lottery-based allocation mechanisms. The usefulness of this body of economic theory in allocation of backcountry recreational resources is addressed through investigation of ability to measure demand for congestible resources, and the problems associated with use of surrogate measures of demand.

Theoretical models of efficient management of congestible resources cannot

be applied with the current state of knowledge because existing non-market valuation methods are not able to identify Hicksian-compensated demand functions for congestible backcountry recreation. Use of Marshallian demand measures introduces the possibility of resource misallocations of unknown direction and magnitude.

**Keywords**

economic, congestion, recreation, management, crowding, welfare, demand, displacement, rationalisation, non-market valuation.

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Public agency decisionmaking

The essence of resource management is determination of the optimal rate of use and the allocation of scarce resources. In other words, decisions must be made regarding how much resource use should occur at any point in time and, since for most resources demand[1] outstrips supply, decisions must be made as to who is permitted to use resources and how much use they may make.

"Optimality" implies there is a set of objectives which resource managers are pursuing. An optimal resource allocation is the allocation that "best" meets those objectives. In the presence of more than one objective and more than one potential resource user there consequently arise problems in making inter-personal welfare comparisons and in trading-off competing objectives.

Resource allocation methods determine (or influence) who uses a resource and how much use they make of it. The optimal methods for allocating scarce resources amongst potential users differ depending upon the objectives of the resource administering agency and the number and characteristics of those wishing to obtain rights over scarce resources. When resource control is held by commercial organisations profit making is an important objective. Consequently, resources are allocated by any of a number of revenue-generating pricing tools, including: fixed prices, discriminatory prices, and auctions.

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[1] If there were no costs incurred by consumers from use of the resource. Costs include, but are not restricted to, monetary costs.

While price allocation mechanisms are necessary to meet profit objectives and can often be shown to meet efficiency goals, the reasons underlying provision of many of the goods and services administered by public agencies are not profit or efficiency based. Goods allocations may be directed at distributional matters, often to meet some minimum standard, or to supply services to which society considers some or all individuals have inalienable rights. Consequently, many public agencies that are primarily concerned for distributional objectives allocate resources by mechanisms other than pricing. Social welfare and health services are often distributed on merit, and there is usually a well defined order for meeting demands; severe head injuries, for example, are likely to be treated before in-grown toenails. Other services are provided free of charge and without any other form of restriction (e.g. street lighting, foot access to national parks), while others are distributed by queuing (state housing), or lottery (hunting permits).

Many New Zealand resources previously allocated by public agencies using non-price methods have recently been, or may soon be, transferred to price allocation, either directly (e.g. the implementation of backcountry hut fees) or indirectly by entrusting distribution to commercial organisations or state-owned corporations (e.g. agricultural advice).

The place of distributional matters in the ways society chooses to allocate resources is emphasised by Zajac (1978, p.1):

> Governmental intrusion in the market place in the name of equity or social justice is widespread. Minimum wage and child labour laws, occupational and safety standards, environmental protection regulations, ceilings on interest rates for home mortgages are but a few examples. There are also obvious forces at work to make the phenomenon more widespread. The natural desire to right apparent wrongs creates pressures to pass laws and regulations to ensure justice is done. But the creation of a law or regulation in turn usually both interferes with the efficient operation of markets and creates a class of persons who gain. The gainers then of course

fight any attempts to repeal the law or regulation.

Zajac's comments are directed at government regulation. They indicate that society is concerned about distributional matters and will go to great lengths to address perceived injustices, including the sacrifice of efficiency. But, regulations are not the only things to influence the actual distribution of resources and their benefits. Resource allocation procedures cause dramatic variations in the allocation of goods and benefits. A lottery, for example, will nearly always result in a different allocation to an English auction.

Public agencies concerned with addressing distributional matters may be required to cover the costs of providing services from income received from their provision, and may also be concerned with matters of efficiency. Choice of a resource allocation tool will therefore need to be made in light of the relative revenue raising and efficiency characteristics of the tools available. These characteristics may act as constraints to adoption of tools which best meet distributional objectives.

In general, therefore, one would expect that public agency adminstrators face a more complex set of objectives than the profit-maximising decisionmakers commonly encountered in the business sector and extensively analysed in the financial and economic literatures. The additional number of objectives alone does not contribute to the difficulty of decisionmaking if those objectives are easily measured (in the manner that profits may be measured) and a relationship detailing how those objectives are to be constructed into one **objective function** is available. In that case, the resource manager could act as a technician to determine which allocation maximises the objective function.

In reality resource managers cannot act as technicians. They are often required to evaluate outcomes against some unknown social objective function. One of their tasks may be to identify objectives. Objectives such as fairness are not commonly measured, nor are there well recognised trade-offs between (say) fairness and efficiency or profits. Resource managers are therefore often in the position of not knowing what information to obtain or how to evaluate it.

Welfare economics has a strong tradition of focusing on efficiency maximisation as a single management objective. A major finding of welfare economics is that individual pursuit of the objective of profit maximisation will lead to an efficient resource allocation if markets are perfect. Analysis addresses the efficiency costs of imperfect markets. Markets for public agency provided goods and services are seldom perfect. The public agency generally acts as a monopolist, or at least a major actor in the market, and its administrators are not answerable to shareholders if they do not produce sufficient profit. Public agencies therefore have the opportunity of selecting from a wide range of resource allocation mechanisms.

## 1.2 Congestion

Congestion is a negative externality. It arises where individual resource users do not have the right to exclude others from resource use and use is partly rival. That is, one person's use of a congestible resource or facility does not prevent others from obtaining benefits from that resource or facility, but the benefits obtained from any given unit of use are inversely related to the total number of resource users. Congestible goods are neither public goods nor private goods. Because resource users do not face the full costs of their use there is a tendency for congestible resources to be overused.

Economic analysis of congestible goods has concentrated on: their valuation, identification of efficient prices, and identification of efficient use levels assuming that prices would be used to allocate use. There remain unanswered questions regarding the efficiency costs of alternative market structures, the efficiency costs of non-price allocation mechanisms, and efficient use levels when non-price allocation mechanisms are employed. Resource sociologists have described several behavioural changes that occur with increased levels of congestible resource use. These behavioural changes have not been explicitly modelled in an economics framework.

## 1.3 Congestion in backcountry recreation

Backcountry recreation commonly refers to resource-based activities such as: tramping, hunting, climbing, fishing, and picnicking. These activites have many welfare-influencing characteristics associated with them. Of particular interest is that many participants in these activities prefer solitude or low user-density experiences, leading to the search for optimal carrying capacities for particular backcountry recreation activities in particular locations. Much of this research has been directed toward identification of carrying capacities without first identifying either the objective function or the method of resource allocation. This methodolgy is therefore theoretically flawed.

Application of economic theory to the analysis of congestible resource management requires knowledge of demand for those resources. This knowledge may be available where goods are allocated via markets (e.g. commercial skifields or toll roads), but is generally unavailable for public agency provided backcountry recreation facilities because they are open-access resources for which no price is charged. Non-market valuation methods have been developed to value public goods, and in some cases can identify demand curves. The application of these methods to congestible backcountry recreation resources, which are neither public nor private goods raises a further issue in their management.

Analysis of congestion in backcountry recreation is clearly within the realm of economics. It is a problem of allocating a scarce resource amongst competing users. The key difference to allocation of private goods is that; with a private good the amount of resource (level of use) is exogenously determined and need only be allocated amonst potential consumers, while optimal allocation of a congestible good requires a decision as to how much use to allow. Pure public goods, on the other hand, present no problems of rivalness so there is no allocation problem, just a need to determine optimal quantity to supply.

## 1.4 Outline of this dissertation

Problems which arise in managing congestible resources can be classified as general or economic in nature. The general problems relate to the deficiencies in existing models of the backcountry recreational experience. Existing models and their limitations are reviewed in Chapter 2, leading to development of a new model in Chapter 3.

There are many problems of an economic nature. Existing theory does not cater adequately for: the problems of more than one type of resource user, behavioural adaptations to increases in user density (displacement and rationalisation), or the role of the allocation method. The first two of these are addressed in Chapter 4. The role of objectives other than efficiency is introduced in Chapter 5. The lottery is introduced as a resource allocation mechanism capable of ensuring process equity. Efficient carrying capacities and efficiency costs for a variety of lottery mechanisms are then derived.

While Chapters 4 and 5 lay the theoretical foundations for management of congestible resources, implementation of that theory requires knowledge of demands for congestible resources. Chapter 6 reviews available non-market valuation methods to assess whether these demands are measurable or not, while Chapter 7 analysis the implications of using imperfect estimates of demand to determine carrying capacities for congestible resources. Empirical verification of the findings is presented in Appendix A.

Chapter 8 summarises the economic theory findings and relates them to the model developed in Chapter 3. The practical implications for management of congestible backcountry recreation resources are then investigated. The chapter concludes with discussion of the limitations of the models constructed here and future research needs.

# CHAPTER TWO

# CARRYING CAPACITY

## 2.1 Introduction

This chapter reviews the history and current thinking with regard to carrying capacity determination. It traces the concept from its roots in ecology to the theory and methods used in its application to current management of outdoor recreation.

## 2.2 Ecological roots

Ecologists have long been interested in the relationships between the number of organisms in an environment, the physical condition of individual organisms and the rate of change in the total number of organisms in populations. Many authors (e.g. Odum, 1959) report that, with very low numbers in a population, growth in numbers is slow while the population becomes established. As numbers increase growth becomes more rapid, but eventually slows as environmental conditions restrict the ability of the population to expand further. These conditions include such factors as disease, lack of food, and social reactions to higher densities (Dasmann *et al.*, 1973:32). This is the sigmoid pattern of population growth. Many authors claim that the upper asymptote of the sigmoid growth curve is the carrying capacity for that species in that environment (Odum, 1959; Ricklefs, 1983; Dasmann, 1959; Moen, 1973). Carrying capacity is therefore the maximum number of individuals of any one species that can be supported in a given habitat. Other forms of population growth functions are also considered, notably the J-form. In this case population growth is also initially slow, followed by a rapid increase, but "stops abruptly as environmental resistance becomes effective more or less suddenly" (Odum, 1959). Carrying capacity is defined as the population level at which this sudden cut-off occurs.

Dasmann (1964:181) suggests three ways in which the term "carrying capacity" is used in the wildlife literature:

1) the number of animals of a given species that a habitat does support.
2) the upper limit of population size above which no further increase can be sustained.
3) the number of animals that a habitat can maintain in a healthy, vigorous condition.

The first two of these uses are positive, and it may be possible to observe or experimentally determine them. The third use is normative, being dependent upon the definitions of healthy and vigorous. This (third) notion of carrying capacity corresponds to that population level which Dasmann describes as optimum density (Dasmann, 1964:184), and at which;

> Body size, health, growth, and fecundity will approach the maximum for the species. Productivity will be near the maximum. Relative to the logistic curve, this level resembles the inflection point of highest yield. .... Since essentially no factor is limiting at an optimum density, it is consequently not a level at which a population would remain except where it is controlled by predators, or by human hunting, or where the behaviour of the animals, through the operation of territoriality, prevents further increase.

Other density levels which may be important in determining population size include: subsistence density, the level at which there is just sufficient food to maintain the population; tolerance density, the level at which intraspecific tolerance permits no further increase; and security density, the level at which a population is normally held by predation or hunting. Dasmann (1964) concludes that it may be possible for optimum density to coincide with either tolerance or security density, but that this is unlikely. Consequently, wildlife managers must act if populations are to be maintained at optimum densities. The carrying capacity concept has been applied to human populations, leading to the conclusion;

> populations can either increase to a subsistence density, a level where human suffering and general misery will be a maximum, or they can be levelled off by self-imposed restrictions on growth, at or near an optimum density. (Dasmann *et al.*, 1973:34)

## 2.3 Human recreation

The carrying capacity concept was extended to the field of human recreation as early as 1951, by J.V.K. Wagar who stated;

> Forestry, range management, and wildlife management are all based upon techniques for determining optimum use and limiting harvest beyond this point. Forest recreation belongs in the same category and will be more esteemed when so treated. (Wagar, 1951:433)

Wagar made it clear that he was not solely concerned with preventing resource degradation, but was also concerned with quality of the recreational experience. To maximise quality he suggested that "Recreational use must be stopped in one place and flowed into another." (Wagar, 1951:434). This concern was further elaborated by J. Alan Wagar (1964) who was concerned that "When too many people use the same area, some traditional wildland values are lost." (Wagar, 1964:2). As a result, recreational carrying capacity was defined as "the level of recreational use an area can withstand while providing a sustained quality of recreation." Realising that it would be possible to sustain many different quality levels, each associated with a particular carrying capacity, Wagar (1964:4) concluded that every carrying capacity must be associated with at least some implicit management objective, so that;

> recreational carrying capacity must be considered as a means to an end, not an absolute limit that is inherent in each area.

In recognising that freedom of access may reduce quality and enjoyment, and that imposition of use restrictions would be necessary to maintain these, Wagar (1964) appears to be confirming Dasmann's (1964) hypothesis that an optimum density is unstable, and implies that unless the (user) population is managed it will increase to its tolerance, or subsistence, density.

Since carrying capacity is dependent not only upon environmental durability and rehabilitation characteristics, but also upon demands for naturalness and solitude it was apparent to Wagar (1964:6) that, to determine an appropriate carrying capacity, it was first necessary to determine the relationship between recreational satisfaction and crowding. The use of the word "crowding" instead of number, or density, of users may have been unintentional, for it appears from the context in which Wagar repeatedly used it that he was referring to "number of people". However, these concepts are not identical and their treatment as such in ensuing analyses has caused considerable mis-understanding.

## 2.4 Tragedy of the commons

Understanding of the mechanism by which a population approaches its subsistence density was popularised by Hardin (1968) in a paper titled "Tragedy of the Commons"[1]. The conceptual foundations for the tragedy of the commons are attributed to Lloyd (1833) who first used the example of many people grazing cattle

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[1] Dasgupta (1982, pp13-14) describes some important errors in Hardin's analysis. Rational actors will consider all their costs of adding additional cattle (not only their reduced output from existing cattle) and will compare those to the value of output from the additional beast. Consequently, it is possible that the commons will be overused but not ruined.

on a common to illustrate the need for checks to human population growth. Hardin describes the operation of the tragedy as follows;

> As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility to me of adding one more animal to my herd?" This utility has one negative and one positive component.
> 1. The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1.
> 2. The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of -1.
>
> Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another....But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit - in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all. (Hardin, 1968:1244)

Like Lloyd, Hardin was primarily interested in determining the optimal size of the human population. He recognised that defining the optimum would be an extremely difficult task. In choosing "the maximum good per person" as his definition of optimality Hardin never tackled the issue of what is good, or how good should be measured. He has, however, made the implicit assumption that "social good" is "mean good" regardless of to whom that good occurs. This objective function reflects Hardin's particular view of the world. Other views would suggest alternative objective functions and hence different carrying capacities (Wagar, 1964).

Hardin viewed the tragedy of the commons as being applicable to things other than biological populations. Amongst these are pollution and recreational resources - "we must soon cease to treat the [national] parks as commons or they will be of no value to anyone." (Hardin, 1968:1245). Hardin's suggestions for possible solutions to overuse of national parks include turning them into private property and allocating restricted rights to enter. While finding these options undesirable, Hardin finds the alternative (destruction of the national parks) even less desirable and so condones mutual coercion through laws, taxes, and other means as appropriate ways to prevent the tragedy occuring. This theme is continued in a later paper (Hardin, 1969) where the relative merits of different methods of allocating wilderness in cases where demand is greater than optimum capacity are discussed.

### 2.4.1 Mathematical exposition

A more general description of the tragedy of the commons may be provided mathematically. Suppose there are k individuals who have rights to graze cattle on a common. The number of cattle grazed by individual i is $n_i$, and the total number grazed by others is $N_i$, where;

$$N_i = \sum_{j=1}^{k} n_j - n_i$$

Selfish individuals attempt to maximise the benefits they each obtain from the common (income from sale of meat, meat for personal consumption, prestige associated with size of herd, etc.) by choosing the number of cattle they will graze. The individual's benefits ($B_i$) are also dependent upon the total number of cattle others graze on the common, as well as other factors.

$$B_i = B_i(n_i, N_i, \text{Others})$$

where,

$$\frac{\partial B_i}{\partial N_i} < 0 \qquad ,\forall i$$

It will be to the individual's advantage to add cattle as long as the net private benefit of doing so is positive. Hence, at equilibrium, given the number of cattle grazed by others, and as long as other conditions are constant, the net benefit to individual i of adding further cattle is zero.

$$\frac{\partial B_i}{\partial n_i} = 0 \qquad ,\forall i$$

However, since there will be less feed available for other people's cattle, their condition will deteriorate and others' benefits will decline.

$$\frac{\partial B_j}{\partial n_i} = \frac{\partial B_j}{\partial N_j} \cdot \frac{\partial N_j}{\partial n_i} < 0 \qquad ,\forall j \neq i$$

Social welfare (B) is assumed to be some function of the welfare of all individuals in society. Adopting the concept of a Pareto improvement in welfare, society's welfare is unambiguously increased (decreased) if the welfare of any individual, or subset of individuals, increases (decreases) while no-one's welfare is decreased (increased).

$$B = B(B_1, B_2, \ldots, B_k)$$

where,

$$\frac{\partial B}{\partial B_j} > 0 \qquad ,\forall j$$

It therefore follows that,

$$\frac{dB}{dn_i} = \sum_{j=1}^{k} \frac{\partial B}{\partial B_j} . \frac{\partial B_j}{\partial n_i} < 0$$

Individual i grazes too many cattle on the common. There is nothing special about i, all other individuals have the same incentives to overgraze from a social viewpoint and so;

$$\frac{dB}{dn_j} < 0 \quad ,\forall j$$

In other words, everyone has more than the socially desirable number of cattle grazing on the common. This result is dependent upon the assumption that benefits experienced by one individual are inversely related to the number of cattle grazed by others, other things being equal. This is the congestion externality. There is partial rivalry for grazing. While the presence of one grazier's stock does not preclude the possibility of other graziers using the common, it does reduce the benefits the other graziers obtain from doing so.

It should be noted that the socially optimal level of grazing (optimum carrying capacity) cannot be determined unless the social welfare function [$B = B(B_1, B_2, \ldots, B_k)$ - Wagar's (1964) management objective] is known. Hardin's (1968) objective of "maximum good per person" is a special case, in which the number of users (k) is chosen to maximise the following expression;

$$B = k^{-1} . \sum_{j=1}^{k} B_j$$

A further special case social welfare function (the Benthamite social welfare function) sums the benefits obtained by all individuals to determine social welfare. i.e.:

$$B = \sum_{j=1}^{k} B_i$$

Adoption of the Benthamite view of the world implies that society is only interested in total benefit, regardless of to whom it accrues. One person obtaining one million units of benefit is just as valued as one thousand people obtaining one thousand units each, or one million people obtaining one unit of benefit each. Alldredge (1973) used a Benthamite view of the world to identify the optimal carrying capacity for a hypothetical wilderness. All (potential) users have identical tastes. Their benefits from a wilderness visit (measured in enjoyils) are dependent on the number of other concurrent users, as shown in Table 1.

TABLE 1. Recreation experience, the simple wilderness case (Alldredge, 1973)

| Column 1 No. of Visitors V | Column 2 Per Person Enjoyment (Enjoyils) | Column 3 Total Public Enjoyment | Column 4 Incremental Total Enjoyment |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1 | 36 | 36 | 36 |
| 2 | 34 | 68 | 32 |
| 3 | 32 | 96 | 28 |
| 4 | 30 | 120 | 24 |
| 5 | 28 | 140 | 20 |
| 6 | 26 | 156 | 16 |
| 7 | 24 | 168 | 12 |
| 8 | 22 | 176 | 8 |
| 9 | 20 | 180 | 4 |
| 10 | 18 | 180 | 0 |
| 11 | 16 | 176 | -4 |
| 12 | 14 | 168 | -8 |
| 13 | 12 | 156 | -12 |
| 14 | 10 | 140 | -16 |
| 15 | 8 | 120 | -20 |
| 16 | 6 | 96 | -24 |
| 17 | 4 | 68 | -28 |
| 18 | 2 | 36 | -32 |
| 19 | 0 | 0 | -36 |
| 20 | -2 | -40 | -40 |
| 21 | -4 | -84 | -44 |

With the addition of successive users to the wilderness the incoming users not only receive less enjoyment than those already there, but also reduce the enjoyment of present wilderness users. If the wilderness use level is not managed use will increase whenever benefits of use for the marginal user are positive. Since individual marginal benefit is equal to per person enjoyment (average benefit) nineteen visits will occur, where average benefit is zero. Total public enjoyment is zero, and incremental total enjoyment (marginal social benefit) is negative, indicating that the wilderness is overused from a social perspective.

In terms of Dasmann's (1964) definitions of use levels Alldredge's wilderness will be used at its subsistence capacity. Optimum (Benthamite) capacity is identified by the use level which maximises total public enjoyment - the use level where marginal social benefit is zero. The Benthamite optimum occurs at ten visits, at which average benefit is positive. Using Hardin's (1968) criterion of "maximum average good" would imply setting optimal capacity at one visitor per time period (the number of visits which results in the maximum in column 2). This example illustrates how optimum capacity can be identified once the social welfare function is known. It also illustrates the degree to which the optimal outcome changes with alternative social welfare functions.

The Alldredge example is vastly simplified for several important reasons. The first is that, for many types of recreation, participants may actually gain increased benefits from the first few encounters. This may occur for reasons of loneliness, education, or safety. Second, it is most unlikely that individuals wishing to use a resource will all have similar tastes. In a wilderness, for example, some hikers may principally be seeking solitude while others may be seeking a more social trip into a pristine environment. In other cases conflict may arise between different types of user. An example of this is the incompatibility of bathing and waterskiing. Third, each individual, whether a user or not, may be concerned with several different aspects of the resource or experience. The value of a trip into the wilderness may depend on much more than the number of encounters. Location of encounters, the nature of the terrain, condition of flora and fauna, amount and type of litter, weather conditions, and so on may all be strong determinants of enjoyment of the wilderness. The effect of number of users on all of these factors must therefore be considered when determining carrying capacity. Hence, the function describing benefits for each individual is far more complicated than that proposed by Alldredge.

That is; $B = B\,(B_1, B_2, \ldots, B_k)$

where; $B_i = B_i$ (weather, litter, trail encounters, camp encounters, flora, fauna, others)

and; litter = g(number of users),

trail encounters = f(number of users),

camp encounters = h(number of users), etc.

## 2.5 The satisfaction model

Because use levels affect social welfare by several different, often complex, paths the simple models introduced by Hardin and Alldredge may need considerable development to be of use in guiding management of backcountry recreation resources. To this end much effort has been expended on developing what has come to be known as the satisfaction model (Heberlein & Shelby, 1977). The simplest specification of the satisfaction model, illustrated in Figure 1, is provided by Manning and Ciali (1980).

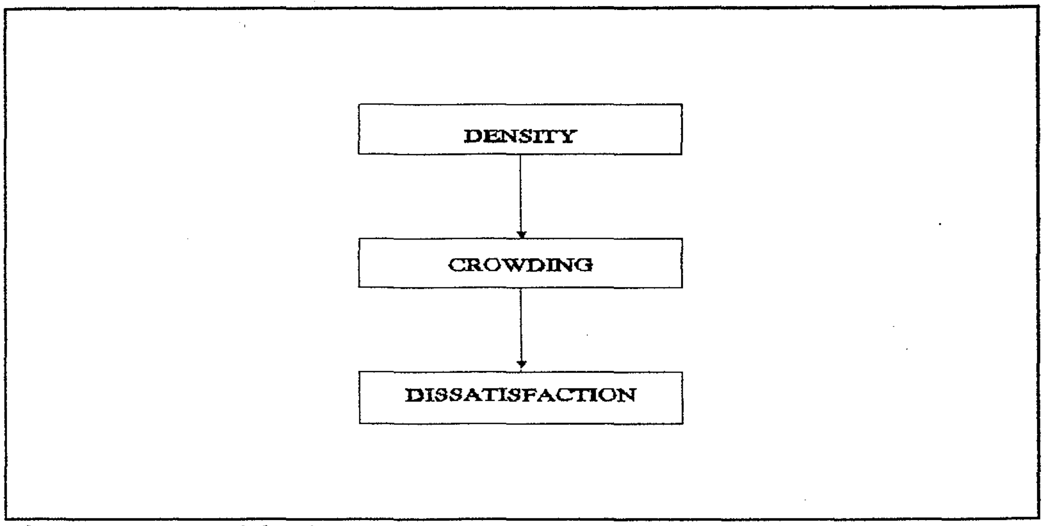


**Figure 1** Satisfaction model

Density, the number of people in a given area, is hypothesised to affect crowding which is defined as "a negative personal, subjective evaluation of some density level" (Manning and Ciali, 1980:330). Further explanation is provided by Stokols (1972:276),

> Crowding ... appears to arise through the juxtaposition of density with certain social and personal circumstances which sensitize the individual to the potential constraints of limited space.

Although termed the satisfaction model, dissatisfaction is the dependent variable because "Quality is normally defined or expressed in terms of dissatisfaction on the part of recreation participants" (Manning and Ciali, 1980:332). Beyond a certain level of crowding users are hypothesised to become dissatisfied. The implied management objective is therefore to avoid dissatisfaction by controlling user density.

The objective is viewed differently by some authors. For example, Lucas and Stankey (1974:14) state. "the goal of recreation management is to maximise user satisfaction." Whether this objective refers to individual or aggregate user satisfaction is unclear in most cases, although Manning (1986:8) alludes to aggregate satisfaction when he states " . . . total satisfaction of all outdoor recreationists might truly be maximised". This confusion is symptomatic of failure to determine an appropriate social welfare, or objective, function.

### 2.5.1 Tests of the satisfaction model

The satisfaction model provides the basis for three areas of research. These involve estimation of the relationships between: crowding and satisfaction, density and crowding, and density and satisfaction. Empirical work has concentrated on the last two of these and is summarised by Manning (1986).

The relationships between the variables in the satisfaction model are either non-significant or very weak (Manning, 1986), implying that factors other than density and crowding are important determinants of satisfaction. Tests of the satisfaction model in its simplest form suggest that user density and crowding are not direct causes of dissatisfaction. This is not to say that they may not have an impact through intervening variables. Contingent valuation has been used to determine satisfaction (willingness to pay) as a function of number of encounters with other parties in the wilderness (Cicchetti and Smith, 1973), and number of people per acre of beach (McConnell, 1977). These approaches employ the same logic as Alldredge (1973), but use willingness to pay as a measure of satisfaction, rather than Alldredge's enjoyils. In both these cases there was no significant relationship between density and satisfaction (willingness to pay) unless other variables were controlled. Even then, the relationships were only of marginal significance. Controlled variables included: length of trip, income, sex, education, and number of weeks of paid vacation per year (Cicchetti and Smith); and family income, days at the beach per season, and air temperature (McConnell).

A similar study (Menz and Mullen, 1981) used willingness to travel, rather than willingness to pay, as the measure of satisfaction. It found that "the expectations of the recreationist concerning the number of interparty encounters affect willingness to travel to reach the site" and concluded; "that those who expect a high level of encounters are less likely to visit an area, *ceteris paribus*, may be an explanation for the zero or low effects of increased encounters that have been found on actual sites" (Menz and Mullen, 1981:38-39). In obtaining these results; family income, education, seasonal visits, days on site, years of experience, and size of party were all controlled. These economic studies compare density, or contacts, directly with satisfaction. They do not include crowding. Each suggests that factors other than density are important determinants of satisfaction obtained from backcountry recreation.

### 2.5.2 Expectations and preferences

Individuals evaluate recreational experiences against their own expectations and preferences for that activity (Absher and Lee, 1981; Bultena *et al*., 1981; Schreyer and Roggenbuck, 1978). There is some evidence to suggest that pragmatic expectations are of more importance in determining satisfaction than are preferences for an ideal experience (Shelby *et al*., 1983). Explanation is provided by Stankey (1972:101);

> If a person expects to find a beach quiet and uncrowded he might experience considerable disappointment if it is not. If, on the other hand, he expects it to be crowded, bustling with people, and it is in fact, he might not be happy with the situation, but his expectations have probably tempered his reaction even though he would have preferred to find it uncrowded.

Expectations and preferences are likely to vary amongst individuals and be directed towards different aspects of the recreation experience. Some people may prefer meeting many others, while others pursue lower density experiences, or solitude. Others may be most concerned about wildlife, peace and quiet, game, natural resource conditions, scenery, or the weather, leading to the conclusion; "How one defines the environmental situation at hand in terms of the functions or tasks one prefers to perform greatly influences perceived crowding." (Hammitt, 1983:314). One implication of the importance of expectations is that dissatisfaction may be reduced by allowing recreationists to form more accurate expectations of the conditions they are likely to encounter, and so direct use to more appropriate locations. This could be attained by better dissemination of information on facilities, alternative opportunities, and likely conditions.

### 2.5.3 Contacts

Shelby (1980) indicates that the correlation of density with encounters is not perfect. For a sample of Grand Canyon river runners density explained only about half of the variation in contacts. In a hiking environment which allowed greater choice of route Bultena *et al.* (1981) found an even weaker relationship between density and contacts (r=.26 - .30). Number of interparty contacts may therefore be an important intermediary between density and crowding or satisfaction. Differences in actual and reported contacts may be large (Shelby and Colvin, 1982), with perceived contacts being the relevant variable in the determination of crowdedness (Shelby *et al.*, 1983).

Characteristics of contacts also appear to be important in determining their effect on satisfaction. Important encounter characteristics identified to date include: the mode of travel of those encountered, e.g. whether with parties travelling on foot or by horse, by powerboat or canoe (Cicchetti and Smith,1973; Lucas, 1964; Stankey, 1972); location of encounters, e.g. on the trail or at a campsite (Cicchetti and Smith, 1973; Gramann and Burdge, 1984; Stankey, 1972); size of groups encountered (Stankey, 1972); behaviour of those encountered (Gramann and Burdge, 1984; Jacob and Schreyer, 1980; Stankey, 1972; West, 1982); and situational variables, including degree of acquaintance interaction, and whether resource users are working or recreating (Cohen *et al.*, 1975). The explanatory power of the simple satisfaction model may be improved by including these other effects.

People are not only affected by encounters with others, but also by evidence of other people having been in the area, as evidenced by: litter, trampling of trails, formation of campsites, fire rings, excretia, toilet paper, and polluted lakes and streams (Stankey, 1972; Bultena *et al.*, 1981; West, 1982)). This aspect of solitude suggests an intertemporal as well as an intratemporal characteristic to congestion effects and their management.

### 2.5.4 Multiple satisfactions

Many elements of the recreation experience are important in determining satisfaction. Hammitt (1982) has explained the various components which interact to determine the nature of "wilderness solitude". These include: the presence of a natural environment, cognitive freedom, the intimacy of a small group of chosen friends, and freedom from societal expectations and obligations. The co-existence of many aspects making up the experience has been referred to as "multiple satisfactions". For example, the reasons an individual has for fishing might include one, some, or all of: sport, exercise, socialise, or to gather food. Recent references to multiple satisfactions (e.g. Vaske *et al.*, 1986) allow for any number of motivations to be important for any individual. However, individual motivations may have relatively different levels of importance for different individuals, hence people who outwardly appear to be doing similar things may in fact be pursuing quite different objectives.

Schreyer and Roggenbuck (1978: 377) draw on Vroom's (1964) theory of expectancy to provide five conclusions which summarise the importance of multiple expectations.

> (1) People have a variety of expectations for participating in recreational activities; (2) the expectations for participating in one recreational activity are usually different from the expectations for participating in another activity; (3) people engaged in the same activity sometimes seek different outcomes; (4) different types of recreationists using the same environment sometimes seek different outcomes; and (5) such antecedent conditions as demographic, socio-economic, and environmental variables have seldom, by themselves, been useful in explaining and predicting the motivations of recreationists.

Since all users are not the same, there arise difficulties in determining appropriate management objectives. These difficulties gain significance because of Schreyer and Roggenbuck's fifth conclusion, which implies that it is impossible to predict recreationists' objectives. It is therefore necessary to directly survey recreationists to determine their objectives. Stankey (1972) has developed "wilderness purism" scales to categorise wilderness users for management purposes according to their responses to survey questions, based on the assumption that members of each category will prefer similar types of opportunities.

The recreational hunting literature has been surveyed by Vaske *et al.* (1986) who identify three main types of satisfactions - bagging game, closeness with nature, and social. The relative importance of particular satisfactions varies with types of species hunted and hunting methods used (Bryan, 1979). Similar findings exist for backcountry hiking, fishing, climbing, canoeing, skiing, and birdwatching (Bryan, 1979).

The implication of multiple satisfactions is that perceived crowding might be an insufficient reason for an individual to rate the experience as unsatisfactory. Explanation is provided in discrepancy theory. Schreyer and Roggenbuck (1978:377) summarise this theory as follows;

> The discrepancy theory posits two major propositions: (1) satisfaction is determined by the differences between the perceived outcomes an individual receives and the outcomes he wants or thinks he should receive, and (2) overall satisfaction in any situation is influenced by the sum of the discrepancies that exist for each facet of the situation.

Consequently, while a recreationist might feel crowded (i.e. there is a large discrepancy between the preferred and actual number of people present) there may be no discrepancies for other elements of the activity, such as: naturalness, success in taking game, within party intimacy, and climatic conditions. The discrepancy arising from crowding may be insufficient to cause the recreationist to rate the experience as unsatisfactory. It is, however, possible that crowding alone is sufficient reason for dissatisfaction. The relationship between density, or crowding, and satisfaction is therefore reliant upon the saliency of user density, or crowding, in the recreational experience (Stankey and McCool, 1984).

Because individuals rank satisfactions from use of a particular resource differently, a cross-sectional study of users will not necessarily indicate any relationship between density and crowding or satisfaction. Furthermore, even if the experience is "crowded" it may still be judged "satisfactory overall" because of multiple satisfactions.

### 2.5.5 Displacement

Potential and existing users who expect that they may be dissatisfied because of high use levels may decide against recreating at high-use sites. Those recreators who do not expect to be dissatisfied because of high use levels continue to use the site. Consequently, crowd tolerant users displace crowd intolerant users in a process known as displacement (Nielsen and Endo, 1977). Displacement is reliant upon the self-selection of recreationists for activities and sites, and is "a move away from an unacceptable situation, rather than a move toward an optimal one" (Becker, 1981:262).

If potential users are well informed about the conditions at various sites it is most unlikely that they would choose to go to a site with a low probability of providing conditions suitable for the type of activity or objectives they wish to pursue. Becker (1981:261) claims that "Dissatisfaction results from expectations which are not realized". Consequently, if recreators at high density recreation sites have freely chosen that site one should not expect them to be dissatisfied unless they have been misinformed about use densities. Further, misinformed users of a site who expected one particular type of experience, but obtained some other, unsatisfactory experience would not be expected to return. Becker *et al.* (1984) cite Skinner's contention that "actions that are rewarded are repeated, [actions that are] discouraged are extinguished" to explain the displacement of dissatisfied site visitors. Studies comparing satisfaction across sites which have different user densities, or even studies of the same site at different points in time, may show no relationship between user density and satisfaction if displacement has occured.

The "Last Settler Syndrome" has been proposed as one mechanism by which crowd tolerant users may displace those who are crowd sensitive (Nielsen *et al.*,1977). This hypothesis suggests that individuals have different density tolerances which, in part, are determined by conditions prevailing when first exposed to the activity in question. If total use of an area increases new users will have accepted the prevailing conditions. Existing users may become dissatisfied with the now higher user density, considering conditions to be crowded when compared to their earlier experiences, and consequently become displaced. In this way, total use may increase over time without a decrease in average satisfaction of users. The question remains as to whether the increased satisfaction obtained by new users is sufficient to compensate for the loss of satisfaction of displaced users - that is, has social welfare been improved?

Empirical confirmation of the displacement and last settler hypotheses is not conclusive. Nielsen *et al.* (1977) report evidence from only one study in support of the last settler syndrome. Nielsen and Endo (1977) divided river-runners into two groups, depending on whether they chose more or less highly used rivers through time, to test their density dependent displacement hypothesis. While some users displayed patterns of behaviour consistent with the hypothesis, most did not. Possible reasons include: the possibility of displacement on other factors, such as seeking more challenging rivers; the supply characteristics of different types of river; other factors determining satisfaction from river trips (such as wilderness setting, trip length, or difficulty); and the possibility that "true displacers" were excluded from the sample because they had stopped using the high use area where the sample was obtained.

In a study of two rivers within the same region, Becker (1981) found that recreators diverted their use from one to the other if they were concerned about use densities and considered these to be preferable on the other river, or if they perceived other environmental conditions to be superior on the other river. Roggenbuck *et al.* (1980) also showed that some canoeists avoided particular rivers because they perceived them to be crowded. Attitude scores (Fishbein and Ajzen, 1975) were used by Anderson and Brown (1984) to predict displacement behaviour of users of the Boundary Waters Canoe Area. They concluded;

> displacement is likely to be caused by more than visual encounters with others. An additional implication is that encounters with others may not be as important to displacing users as other outcomes. (Anderson and Brown, 1984:71)

Anderson and Brown's "other factors" in determining displacement include: litter, worn-out campsites, knowledge of available alternatives, propensity to explore new areas, as well as changes in lifestyle, income, and leisure time, amongst others.

Failure to recognise the consequences of displacement can result in suboptimal management of the resource.

> Decisions should be based upon the relative congruence of expectations with the management goals for the resource. If objectives are not set in terms of providing specific experience opportunities, then the assessment of crowding will be a function of the average perceptions of the present users, regardless of the nature of their expectations. Present users will have a low threshold of crowding if density-dependent experience expectations are most important to them. However, a problem with such management strategies is that there is a competitive advantage for density-independent experiences. In an open system with increasing overall demand, those who have experience expectations that are most independent of density will be able to stand increasing levels of use in an area and still maintain high degrees of satisfaction. Over time, such individuals will constitute a proportionately larger percentage of total users. Those with higher density-dependent expectations will likely seek other opportunities, as they will not be able to maintain their satisfaction. Assessments of the average perceptions of crowding of these groups over a time period will therefore tend to support higher use levels. Thus, a decision not to manage to provide opportunities for specific experiences is in fact a decision to manage for density-independent experiences. (Schreyer and Roggenbuck, 1978:391-392)

## 2.5.6 Rationalisation

Leaving a crowded situation is not the only reaction that could mask a density-satisfaction relationship. An alternative is the adoption of "perceptual and cognitive modes of reducing the salience of restricted space". That is, "the person may modify his standards of spatial adequacy, enhance the attractiveness of the task, or attempt to achieve a greater degree of coordination with others in the group, as a means of alleviating the sensation of crowding" (Stokols, 1972:276). This course of action has been termed "rationalisation" (Heberlein and Shelby, 1977), and "product shift" (Shelby *et al.*, 1986). Rationalisation implies that resource users may report their experiences to have been satisfactory in cases where they were not, at least in terms of their initial objectives for the use.

Festinger's (1957) theory of cognitive dissonance provides the conceptual foundations for the rationalisation hypothesis.

> cognitive dissonance is a state of tension that occurs whenever an individual simultaneously holds two cognitions (ideas, attitudes, beliefs, opinions) that are psychologically inconsistent. ... Because the occurrence of cognitive dissonance is unpleasant, people are motivated to reduce it; this is roughly analagous to the processes involved in the induction and reduction of such drives as hunger or thirst - except that, here, the driving force is cognitive discomfort rather than physiological discomfort. ... how do we reduce cognitive dissonance? By changing one or both cognitions in such a way so as to render them more compatible (more consonant) with each other, or by adding new cognitions that help bridge the gap between the original cognitions. (Aronson, 1976:88-89)

One means of reducing cognitive dissonance is to change experience definitions. If, for example, more people than are desired are encountered on a wilderness trip the solitude seeker may redefine the experience to be moderate-contact and therefore remain satisfied (Shelby, 1980). The possibility that this person would be more satisfied with less contacts is not precluded. Manning and Ciali (1980) suggest that rationalisation may only be an appropriate response where recreational users have made a considerable investment of time or effort to undertake an activity. They suggest that for routine, day use type activities there is little to be lost by admitting that the experience was unsatisfactory. In other words, cognitive dissonance resulting from unsatisfactory, low investment activities will probably be less intense than for unsatisfactory, high investment activities.

### 2.5.7 Satisfaction

The concept 'satisfaction' is not used consistently by all authors. Some imply that it alone can be used to rate an experience in a range from 'not satisfied' to 'very satisfied'. Others seem to treat it as a broader concept, allowing people to be dissatisfied as well as satisfied. Stankey and McCool (1984) conclude; "attitudes lie along two continua from, for example, not satisfied to highly satisfied, or not dissatisfied to highly dissatisfied, rather than one continuum from satisfied to dissatisfied." (Stankey and McCool, 1984:462). Heberlein (1977:70) suggests that the point of dichotomy between satisfaction and dissatisfaction is most important to field managers since "managers say they wish to provide for as many satisfied visitors as possible. Dissatisfied visitors are a problem for managers; so is turning away other visitors who might be satisfied with the experience."

The focus is different for different studies because of implicit acceptance of different management objectives. Some studies view the maximisation of individual, or mean, user satisfaction as their management objective, while others want to avoid user dissatisfaction.

It may be appropriate to adopt a different name for the output from recreation experiences in order to overcome the ambiguity associated with satisfaction. One possible choice is utility, or welfare, which is a continuous variable and still allows for the inclusion of the dichotomous satisfaction/ dissatisfaction concept. The dichotomy may occur where net welfare is zero, or where the difference between expected and actual welfare is greater than some threshold. Objectives for management could be expressed in terms of maximising (for example) individual, social, or mean welfare; or ensuring that [one of] these reach certain minimum standards.

Adoption of such a measure introduces problems not present with satisfaction. The measure would need to be cardinal to be used with each of the management objectives suggested above. Use of such a measure would force management to decide how benefits are to be measured in practice, and to express their willingness to trade-off benefits accruing to different types of user. It is easier to determine whether someone is satisfied, or not, than to find some theoretically non-existent cardinal measure of welfare. However, if 'being satisfied' is not an appropriate management objective the addition of cardinality cannot be avoided.

## 2.6 Extensions to the satisfaction model

Shelby (1980) and Manning (1986) have developed more comprehensive models which incorporate the elements explaining the failure of the simple satisfaction model to adequately model recreational behaviour.

### 2.6.1 The Shelby model

Shelby's (1980) model is illustrated in Figure 2.

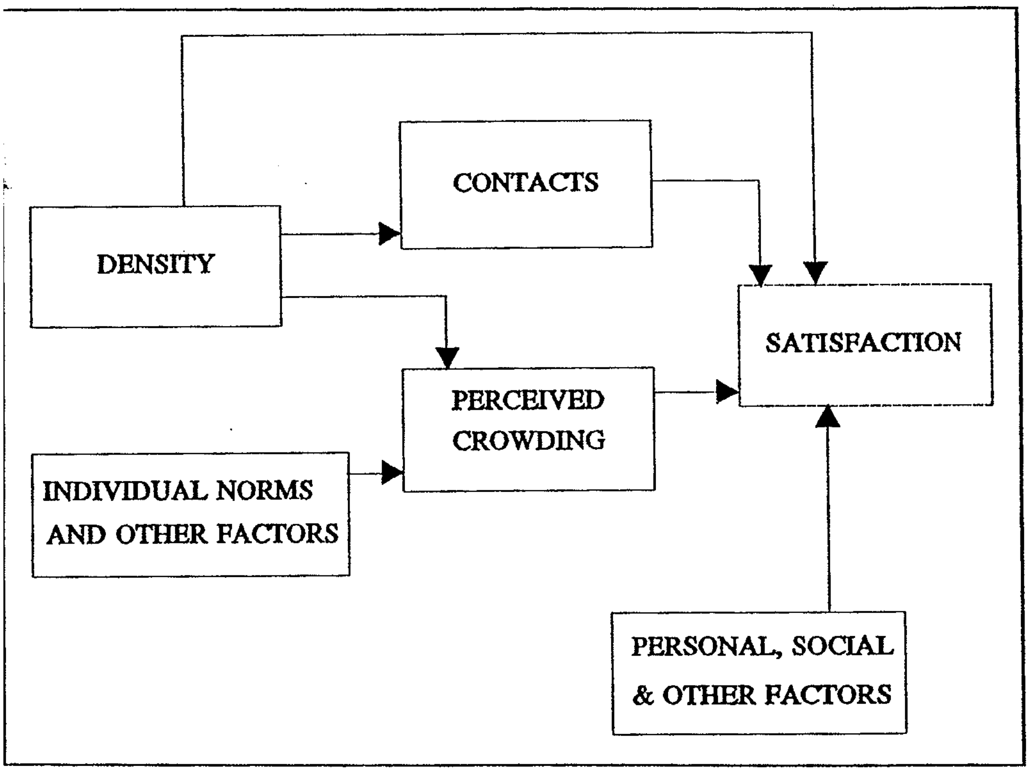


**Figure 2** Shelby's crowding model

Shelby describes his model in the following way;

> (1) Encounters are a function of density, but other factors will also have an effect. (2) Perceived crowding is a function of density, encounters, preferences and expectations, and situational definition. Preferences, expectations, and situational definition may have a greater effect on perceived crowding than density and encounters. (3) Satisfaction is a function of density, encounters, perceived crowding, and other factors; but other factors may have a greater effect on satisfaction than density, encounters, or perceived crowding. (Shelby, 1980:45)

In testing this model for Grand Canyon river runners Shelby found that;

> Density has a substantial effect on interaction, accounting for almost half the variation in contact rates. Density and interaction have virtually no impact on perceived crowding, although individual expectations and values have a major impact, explaining 49% of the variance. Density, interaction, and perceived crowding are not strongly related to satisfaction. Other noncrowding variables explain 31% of the variance in satisfaction. (Shelby, 1980:50-52)

Shelby's findings suggest that manipulation of user densities may have little impact on satisfaction obtained from recreation experiences. However, the model is not adequately specified to make this conclusion, since two of the elements are not explicitly included. Rationalisation could possibly be included in 'personal, social, wilderness, and other factors', but displacement does not enter the model. Shelby acknowledges these points when he claims that;

> satisfaction is probably not a useful criterion for managing use levels. ... It often appears that nothing changes at high encounter levels as long as people are satisfied and healthy. But it is clear that something changes and that 'something' is the nature of the experience. (Shelby, 1980;53-54)

## 2.6.2 The Manning Model

Manning's (1986) crowding model, illustrated in Figure 3, is remarkably similar to the Shelby model, but includes the displacement process, and includes other factors which help explain the density/contacts relationship more fully. It also recognises that researcher perceptions of contacts and satisfaction are likely to be dependent on the methods of measurement, and therefore are likely to differ from user perceptions.

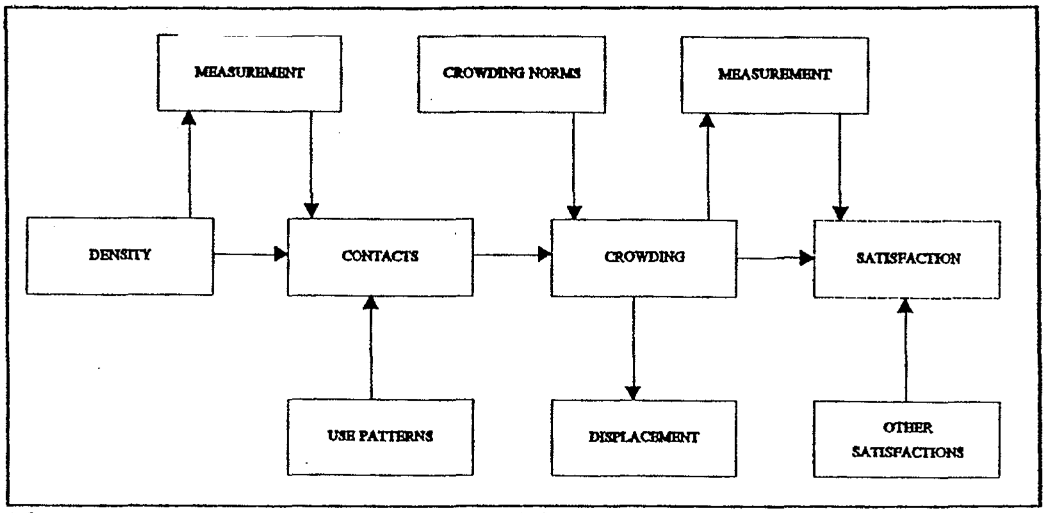


**Figure 3** Manning's crowding model

Manning's graphical model is at variance with his text. For example, the text clearly indicates that the researcher may not get accurate measures of contacts because of the measurement techniques used (page 73), while the diagram suggests that the method of measuring density partially determines the actual number of interparty encounters. The measurement method employed will, however, determine the researcher's perception of the relationship between density and contacts. Similar problems arise with measurement of satisfaction. Manning claims (page 77) that "The relationship between crowding and satisfaction depends on how satisfaction is measured". It is presumed that he refers to the researcher perceived relationship, in which case the ability to accurately measure crowding must also be brought into question. Errors in measurement of contacts, crowding and satisfaction may be reasons for the low explanatory power of the simple satisfaction model.

An important error appears to have been made in relation to the displacement process. Manning suggests that displacement occurs only because of crowding. However, it is apparent from the literature that Manning cites (Neilsen and Endo, 1977; Becker, 1981; Anderson and Brown, 1984) that displacement occurs for a multitude of reasons and, further, that even if someone feels crowded they may still be satisfied and consequently not be displaced. These arguments lead to the conclusion that displacement should be a result of dissatisfaction, whatever the cause, and not just crowding. While rationalisation is not explicitly included in this model it could conceivably be incorporated amongst 'other satisfaction variables'.

## 2.7 Management models

The Manning and Shelby models do not fully define the term satisfaction. Essentially, these authors have not clearly specified management objectives. Since the evidence upon which their models are constructed measures satisfaction of individuals the objective of these models is assumed to be (maximum) individual satisfaction. This, along with the displacement process, reduces the usefulness of these models for making management decisions designed to provide satisfying experiences of a pre-determined nature. The need for clear management objectives is identified in two separate frameworks for carrying capacity determination.

### 2.7.1 Limits of acceptable change

Stankey and associates have formalised the "Limits of Acceptable Change" approach to backcountry management (Frissell and Stankey, 1972; Stankey, 1973; Stankey and McCool, 1984; Stankey *et al.*, 1986). Rather than attempt to decide how much use is too much, the limits of acceptable change (LAC) approach concentrates on the types of conditions required for specific activities. These conditions relate to both the physical state of the resource and the nature of the experience.

> The basic premise of the LAC concept is that change is a natural, inevitable consequence of recreation use. Both environmental and social changes are involved. Acceptance of this premise immediately redefines the traditional question about carrying capacity from 'How much use is too much?' to 'How much change is acceptable?' (Stankey *et al.*, 1985;527)

The shift of emphasis to conditions is a result of the complexity of the relationship between use levels and conditions. It emphasises the need for personal judgements to determine what is acceptable; as well as where, and to what degree, change should be allowed to occur. Stankey (1973) provides a pictorial representation of the LAC management process, reproduced in Figure 4.

The LAC process recognises that both ecological and recreational aspects are important in wilderness, and that they are both subject to change from a range

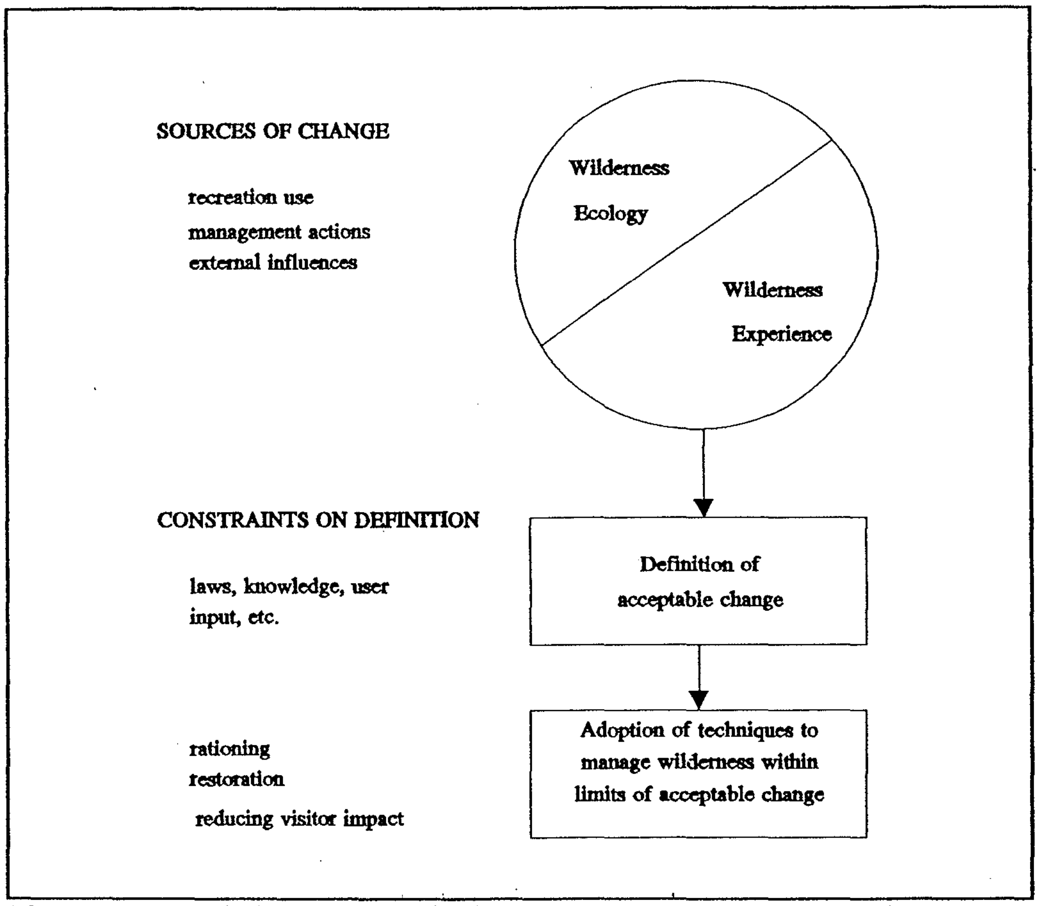


**Figure 4** Limits of acceptable change management process (Stankey, 1973:3)

of factors. Once a decision has been made on the acceptable limits of those changes, techniques can be adopted to limit the factors causing the changes so that conditions remain within the acceptable range. A step by step procedure for implementation of LAC is reported in Stankey *et al.* (1986) and is presented in Figure 5.

The LAC planning system involves nine steps. Step one involves deciding upon the important aspects of management to which the LAC process may be applied. Steps two through four indicate the potential for parts of the management area to be allocated to different types of recreational opportunity, that is, identifies the physical constraints upon management choices. Step five involves identification of specific standards for different opportunity types, while step six generates some possible allocation scenarios. Steps seven and eight involve evaluation of the

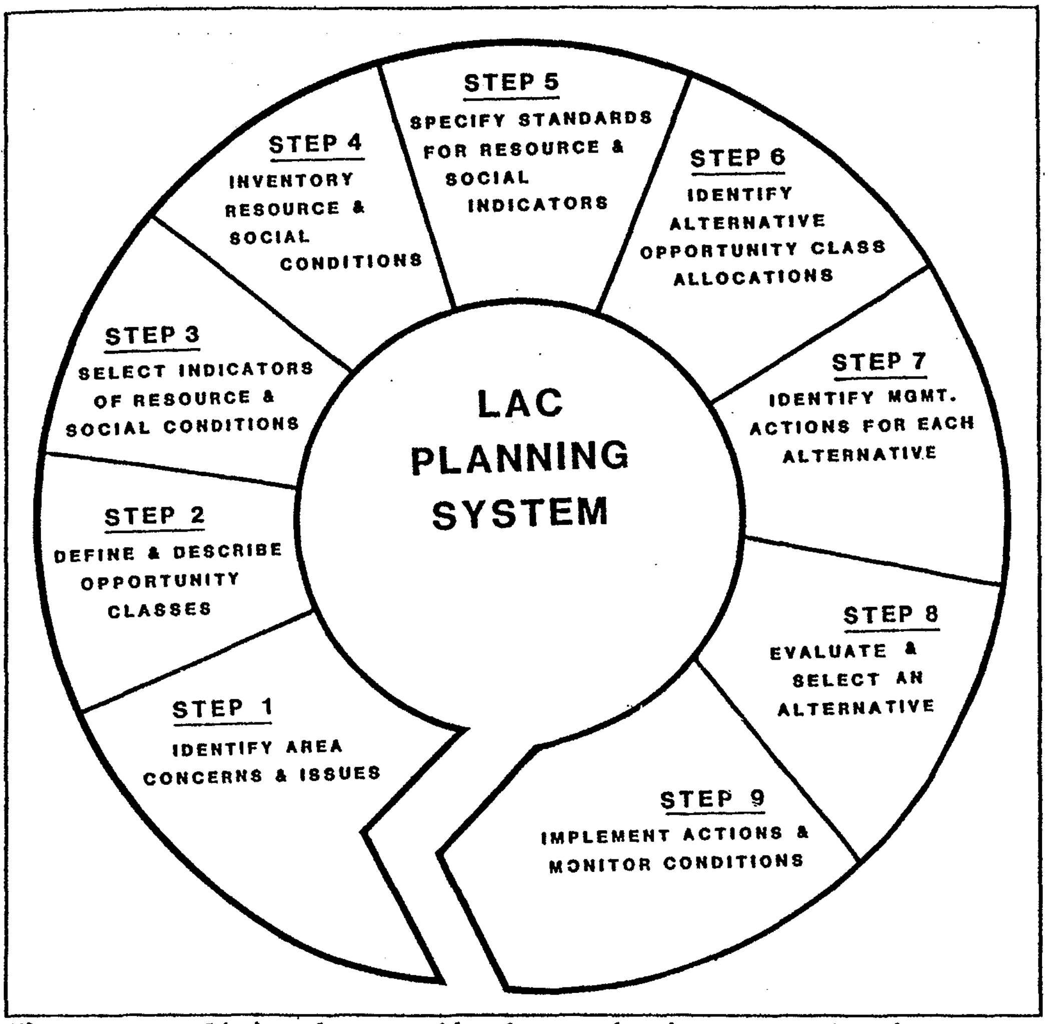


**Figure 5** Limits of acceptable change planning system (Stankey *et al.*, 1986:528)

implications of alternative choices and selection of a preferred allocation of the resource amongst opportunity types. Implementation and monitoring occur in step nine.

The LAC approach takes management beyond the sphere of identifying cause and effect type relationships, although these are also part of the approach. Emphasis is placed on the importance of the effects of use, forcing management to state explicitly the types of experiences an area is desired to provide. According to Graefe *et al.* (1984:421);

> the definition of the type of experience to be provided in a given area in essence requires a decision favouring one user group over competing groups seeking different types of experiences. While resource managers may be reluctant to make such decisions explicitly, it is important to recognise that this judgement is inherent to the carrying capacity question and will occur by default if not deliberately introduced.

Burch (1984) is critical of much of the carrying capacity research, believing it has been looking for technical solutions to a value judgement problem. He suggests that regulating access to public lands is a political, rather than scientific, matter because of class conflict and social equity issues. This view is clarified by Becker *et al.* (1984) who indicate that a computational (technical) solution to a problem can only occur when there is a "high level of concurrence on social values and on scientific fact". In the carrying capacity case 'scientific facts' include the relationships between use levels and encounters and physical impacts on the resource. 'Social values' include information on the relative values of different physical and social outcomes. Knowledge of scientific facts and social values varies according to the management problem, leading Becker *et al.* (1984) to suggest the strategies for decision formulation shown in Figure 6.

| | | SOCIAL VALUES | |
|---|---|---|---|
| | | Agree | Disagree |
| SCIENTIFIC FACTS | Agree | Computational | Political |
| | Disagree | Judgemental | Inspirational |

**Figure 6** Strategies for decision formulation - the relationship between values and facts

Since social values for backcountry recreation are not obvious (Burch, 1984) then, even when the 'scientific facts' are known, determination of carrying capacities must remain a political decision. The proponents of the LAC approach argue that the scientific facts are so complex that it is unlikely they will be understood, but that social values should be provided to resource managers from some external source, such as government. This information structure forces decisionmaking into the judgemental realm (for the area manager, since social values are given), where the scientific fact of 'use level is too high' is determined by monitoring key indicators of social and physical conditions.

## 2.7.2 Shelby and Heberlein conceptual model

A conceptual framework with close parallels to the limits of acceptable change framework is that provided by Shelby and Heberlein (1984); it is illustrated in Figure 7.

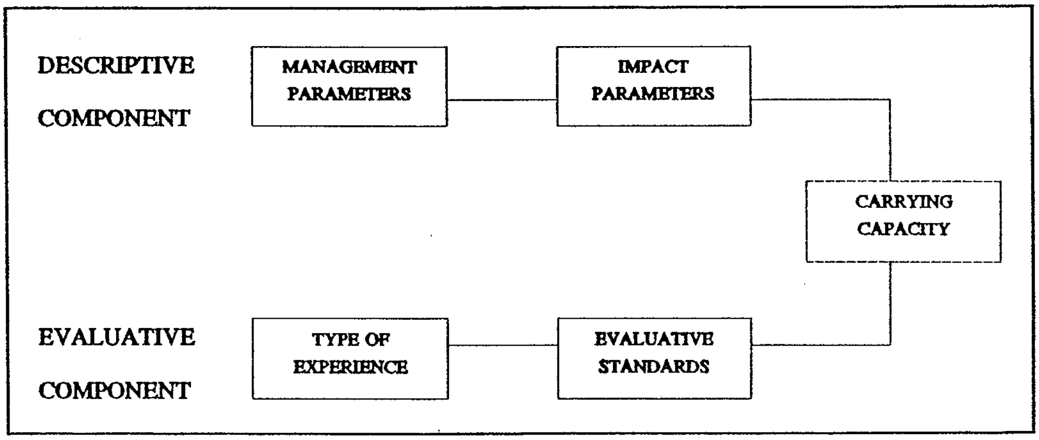


**Figure 7** Shelby and Heberlein's conceptual framework

Shelby and Heberlein's framework takes care to separate the descriptive and evaluative components of carrying capacity determination. Management parameters are those aspects of the resource, and its use, over which managers have control. These include: level of use, type of use, behaviour of users, dispersion of use through time and space, education of users, as well as physical measures such as the provision of huts, tracks, campsites, signs, and so on. Management parameters are actions taken by managers which influence the condition of the resource and the types of opportunities that are provided for resource users. The characteristics and opportunities which eventuate are the impact parameters. Some examples of backcountry recreation impact parameters include: condition of trails and other facilities, displacement of wildlife, presence of litter, and number of encounters with other users.

The evaluative component contains two elements. One is the type of experience that is sought, either by users or by management. This element represents a general statement of the objectives for management. Given the type of experience desired (e.g. pristine, low density, low amenity) there is a set of evaluative standards which determines whether the desired type of experience has been obtained. These criteria are measurable definitions of acceptable levels of impact for particular experiences. For example, a low density experience might be defined as having less than two interparty encounters per day.

The descriptive component describes the state of the resource and the physical conditions recreators will experience for given management parameters. The evaluative component describes the level of impact parameters appropriate to any desired type of experience. Both components are therefore necessary to determine carrying capacity for any particular type of experience. It is also apparent that limiting numbers of users may not be the only means of achieving a desired level of encounters. Other management parameters which may affect the encounter impact parameter include scheduling use, redirecting use, and providing extra facilities or alternative opportunities for users.

The Shelby and Heberlein model, like the LAC model, places the determination of carrying capacity in a different light to the satisfaction models in that it includes some objective for management. Shelby and Heberlein clarify;

> the evaluative component critically considers the different objective states produced by management parameters in an effort to determine their relative merits, and it is here that values enter the model. Management objectives defining the things an area should provide are official statements of value judgements. ... Most carrying capacity conflicts do not revolve around resource questions, but rather around questions about values. .... Social carrying capacity is the level of use beyond which experience parameters exceed acceptable levels specified by evaluative standards. (Shelby and Heberlein, 1984:438-443)

Shelby and Heberlein establish three conditions necessary to determine social carrying capacity.

> 1) there must be a known relationship between use level or other management parameters and experience (impact) parameters
>
> 2) there must be agreement among relevant groups about the type of recreation experience to be provided
>
> 3) there must be agreement among the relevant groups about the appropriate levels of the experience (impact) parameters

The second condition is important if carrying capacity is to be determined in a computational manner (Becker *et al.*, 1984; see Figure 6). However, it appears most unlikely that this condition will be satisfied in practice. Carrying capacity could still be determined in the absence of this condition, but would be reliant upon a value judgement as to the relevant objectives for management, requiring a political solution.

### 2.7.3 Comparison of management models

The Shelby and Heberlein and LAC frameworks are two ways of looking at the same thing. The LAC approach is more general in that it allows for a choice between different scenarios, whereas the Shelby and Heberlein approach relies upon a single statement of what the type of experience is to be. However, given the type of experience desired, the Shelby and Heberlein approach requires selection of a set of standards (evaluative standards) against which actual conditions (impact parameters) are compared. This determines whether actual conditions are consistent with the desired experience type, and hence determines if the number of users (or other things - management parameters) needs to be changed to provide the desired experience. The elements of the Shelby and Heberlein approach therefore match those of the LAC approach.

Neither approach is clear on the source of the decision of appropriate experience type, although Shelby and Heberlein seem to imply that users should agree on this (their second condition for determining carrying capacity), while the LAC approach is suggestive of a political decision. Burch (1984) believes that user agreement is unlikely to be forthcoming, necessitating a political decision.

## 2.8 Conclusions

There have been two major approaches toward modelling the role of congestion in backcountry recreation. The first is based on the satisfaction model. This approach has encountered difficulties in implementation because it does not have well defined management objectives. Satisfaction is an inappropriate objective because of difficulties in determining social satisfaction from individual measures of satisfaction, and because of the displacement and rationalisation processes. The second major approach has been in the area I have defined as 'management modelling'. These models identify the need for specific management objectives, but they do not describe all of the processes occuring at recreation sites, or all of the issues that must be addressed by managers. Consequently, neither of these model types is well suited for application to management of backcountry recreation resources. However, each model offers important insights into recreation management. Consequently, an extended model, incorporating elements of both types of model and addressing the concerns raised about them is developed in Chapter 3.

# CHAPTER THREE

# A NEW MODEL

## 3.1 Introduction

This chapter builds upon the Shelby and Manning models to develop a more comprehensive conceptual model of recreation. It would be possible to expend great effort developing sophisticated models which incorporate all impacts and feed-back loops. It is not the objective of this chapter to build such a model. The aim is simply to incorporate the major linkages and deficiencies identified in existing models to gain as clear as possible a picture of current understanding of the role of management in determining system outcomes. The reason for building such a model is to identify the areas in which resource economics can offer insights into the understanding and evaluation of components of the management process, and to clarify the limitations of the role of current economic modelling as an input to congestion management.

To be complete, a model must show the impacts of all salient factors on individuals' behavioural choices, the impacts of those choices on aggregate outcomes, and how well those outcomes meet management objectives. Deficiencies in the models presented so far raise several important questions which must be addressed in constructing a complete recreation model, including:

1) How can different and/or multiple management objectives be included in one model?

2) How is actual use level determined, and how do management actions influence use level?

3) Management imposes costs, either in money terms or by consuming valuable resources, or more indirectly through the "environmental costs" of the impacts occurring because of management actions. Where do the costs arise, and how should they be incorporated into the model?

4) Where do costs to resource users arise, and how do they affect the benefits obtained from the resource?

5) How should the differences between actual, user perceived, and researcher perceived measures of impacts be incorporated?

6) How can the displacement process be included?

7) Displacement and price-induced substitution effects may induce price and demand changes for other resources. How should these changes be incorporated?

## 3.2 Management objectives

Management objectives and their inter-relationships may be specified in an objective function. The role of the objective function is to specify whose benefits and costs are considered, what types of benefits and costs are considered, how the timing of those benefits and costs is considered, and how trade-offs between categories of benefits and costs are to be made[1]. The objective function provides a means of comparing the net social value of alternative sets of outputs. Its ultimate role is to determine which of a feasible set of management alternatives yields the greatest social benefit.

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[1] Alternatively, how different categories of costs and benefits are to be aggregated into a measure of social benefit.

The specification of an objective function is a value choice and consequently can take only a general form in this theoretical analysis. The models reviewed in Chapter 2 identify only three major objective components. The total benefits accruing from a recreation site depend on:

(i) net benefits obtained by specified individuals,

(ii) environmental conditions *per se*, and

(iii) net costs of managing the site.

In other words, the objective function has the following specification:

$$SW = f(\mathbf{B},\mathbf{E},NMC)$$

where; SW is the (scalar) magnitude of social welfare,

**B** is a vector of individual net benefits,

**E** is a vector of environmental conditions, and

NMC is net management costs.

This specification identifies the trade-offs between benefits received by different individuals and accruing to different groups (individuals, the environment, and management). It also identifies whose benefits are included through specification of the vector **B**. Specified individuals may be: society in general, existing facility users, or a target group of (potential) facility users (e.g. mountaineers, horse trekkers, or family groups of walkers), amongst others.

Individual net benefits may be treated in one of two ways: they may be ascribed a value by the decisionmaker, or they may be determined by the individual in accord with the doctrine of consumer sovereignty. In the second case, individual net benefits are determined by individuals' utility functions, and the opportunities and prices faced[2], i.e.:

$B_i = f_i(O_i, C_i)$

where; $f_i$ is individual i's utility function,

$O_i$ is the set of opportunities available to individual i, i.e. the impacts at all sites, and

$C_i$ is the set of costs faced by individual i, including time and money prices of facility use.

The inclusion of the vector of environmental conditions and individual net benefits in the objective function suggests that environmental conditions have some role in social welfare apart from their contribution to human well-being. It therefore follows that the contribution of environmental conditions to social benefits depends upon the decisionmaker's view on the relevance of intrinsic values. Various definitions of intrinsic value exist (Pauls, 1990). Here, intrinsic values are defined as those values which exist in the resource, regardless of the existence of humans to value it. Anthropocentric values include use and existence values, where existence values are the value to humans of knowing that a resource exists in a specific state, whether that value is because of the benefits obtained by present or future generations (Krutilla, 1967). If management is concerned only with anthropocentric values, then all values are captured in individual net benefits, which are determined by evaluation of the state of the resource in relation to the individual's preferences. For some people benefits may come directly from use of

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[2] Both the Manning and Shelby crowding models conclude that each individual's satisfaction from resource use is determined by a variety of impact parameters and the individual's norms for the activity. Impact parameters can be manageable (e.g. the amount of use by the individual, the number and type of interparty contacts, degree of trampling of vegetation, type and quantity of litter) or non-manageable (e.g. weather conditions, the presence of biting insects).

the resource, while others may receive only existence benefits. Combinations of benefit sources are possible.

Management concern with intrinsic values[3], as is required under the Environment Act 1986, causes some conceptual difficulty (Pauls, 1990). There is no means of accounting for intrinsic values in decisionmaking - there is no metric with which to measure intrinsic value, humans have no means of determining which of two states yields more intrinsic benefits, and there is no way of determining how to make trade-offs between intrinsic and anthropocentric values. For these reasons intrinsic values are not addressed further. This study adopts a strictly anthropocentric view of the world and attention is focused solely on anthropocentric values, allowing the state of the environment to be left out of the social objective function. This should not be interpreted to imply that the state of the environment is unimportant, simply that all of its impacts are measured through individual human benefits. The foregoing relationships are presented in Figure 8.

It may be argued that inclusion of both objective function and net social benefit elements in this model is redundant. This is not the case. The objective of management is to maximise social net benefits. Social net benefits are defined by the objective function. Changing the objective function may change the level of social benefits obtained from the resource, *ceteris paribus*. The objective function is a choice variable, and is therefore an input to this model. Net social welfare is an outcome. Changes in management parameters may result in a new level of social benefits when the objective function remains unchanged.

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[3] Assuming an objectivist definition of intrinsic value. In other words, value that exists in an object irrespective of any values placed upon it by humans. An alternative form of this definition is: the value an object would have if there were no humans to value it.

forth. Since it is widely accepted that each rationing method has unique effects upon who is excluded (Stankey and Baden, 1977; Shelby and Danley, 1979; Cullen, 1985), it is apparent that rationing methods affect not only the level of use, but also the type of user and patterns of use.

Recreational site demand depends upon a range of factors, summarised in Walsh (1986). The most important demand determinants are:

1) Individuals' tastes and preferences (utility functions), which are largely determined by socioeconomic factors such as: age, education, gender, income, and ethnicity.

2) Constraints on individual use[6]. Each individual has a limited quantity of inputs needed to produce recreational experiences (e.g. time and money) and different experiences use those resources in different proportions. These two factors combine to constrain individuals' choice sets; they also imply that individuals with identical tastes and preferences may choose different recreational activities, locations, and intensity of use.

3) Individuals' expectations with regard to the conditions that are likely to be experienced at the recreation site (impact parameters). This is often referred to as site attractiveness or quality, and includes congestion impacts (Walsh, 1986);

4) Opportunities provided at other sites, or by alternative activities. These include the physical availability of substitute sites and activities, their quality, and the costs (monetary and otherwise) of use of those sites.

Hence, a general individual demand model may be expressed mathematically as:

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[6] Bialeschki and Henderson [illegible] used a telephone survey of randomly selected Wisconsin households to identify constraints to recreational trail use. The major constraints (in decreasing order of frequency cited) were: time, information, money, health, availability, safety, and age.

$Q_{ij} = f_i(C_i,P,E_i)$

where; $Q_{ij}$ is individual i's demand for use of facility j,

$f_i$ represents individual i's tastes and preferences,

$C_i$ is a vector expressing individual i's endowment with inputs (e.g. time and money) necessary for facility use,

**P** is a vector of inputs required for use of facility j and all other facilities (e.g. time and money prices), and

$E_i$ is a vector of individual i's perception of impact parameters at facility j and all other facilities.

Each determinant of demand has impacts on both type of user and type of use[7]. For example, a reduction in work hours could allow people to travel to more distant sites, spend more time at close sites, or penetrate further into remote areas. Alternatively, if people expect that a trail is poorly defined, whether it is or not, they will use this information when deciding whether to use the trail. Those seeking pristine conditions might well be encouraged to use the trail, while those seeking an easy walk are likely to be discouraged from use.

Figure 9 illustrates the determinants of actual use. Use has several aspects, including: type of user, spatial distribution, temporal distribution, and type of activity. Many of these aspects will be important determinants of the impacts of an individual visit. Location, timing and type of use, for example, are all likely to greatly influence both environmental impacts (e.g. erosion) and social impacts (e.g. encounters with others).

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[7] Type of user refers to groups of people undertaking the same activity, but who have differing objectives for doing so. Examples include backpackers who may undertake their activity for social, escapist, or aesthetic reasons. Type of use refers to different activities, such as backpacking and motorcycle riding, which can occur at the same location.

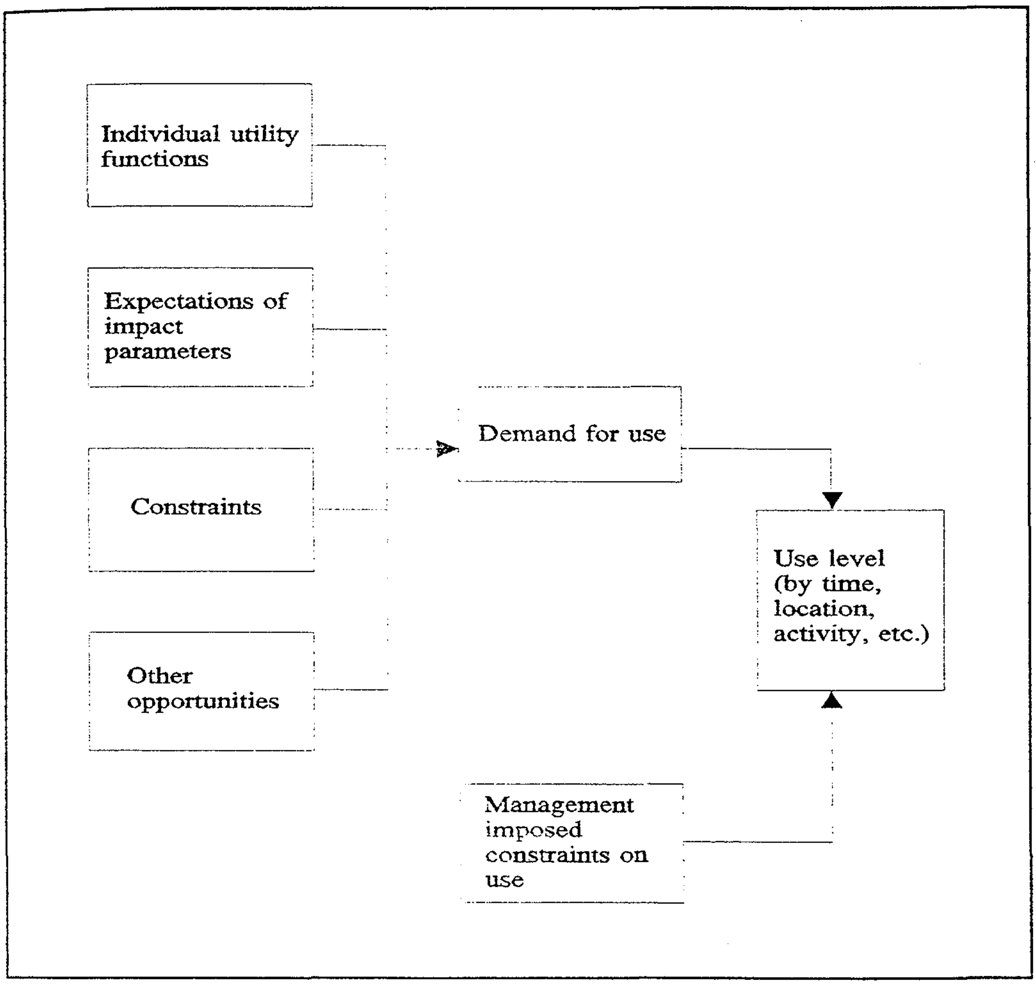


Figure 9 Determinants of actual use

## 3.4 Management costs

Costs of managing a resource may be categorised as direct or indirect. Direct costs are those costs which fall upon the manager as a result of management actions. Indirect costs may arise because of impacts of management actions on others, for example in terms of foregone resource user benefits. Direct management costs arise from three main sources:

1) The supply of services or facilities which are independent of use levels (fixed costs). Examples include national park visitor displays and the initial provision of huts, trails, and signposting in backcountry areas.

2) Other costs are dependent upon the amount, location, and type of use actually experienced (variable costs). Rubbish removal, trail maintenance, and search and rescue costs largely fall into this category.

3) Further management costs occur when management places constraints on use. Administration of quotas, issue of permits, and entrance fee collection, for example, are all likely to require expenditure of both time and money. Depending on the type of allocation mechanism adopted, varying proportions of fixed and variable costs will be incurred. The costs of administering use limits are determined by two main factors; the type of allocation mechanism chosen, and the number of people wishing to gain access to the resource. An example of the latter impact is provided by reservation systems, where greater demand for access increases management costs because each application requires manager interaction. The same is not true for effort restrictions, such as closing-off access roads, whose costs are independent of demand. Some resource allocation mechanisms (e.g. entrance fees) generate income for management agencies. When those tools are used, it is conceivable that net direct management costs could be negative (i.e. the revenue generated from use of such a tool could more than cover the costs associated with use of the tool. For example, it may be necessary to build and staff entrance stations to collect an entrance fee, but the revenue collected could exceed those costs, generating a net cash inflow for management).

It should be noted that direct management costs could be avoided by: not providing or maintaining any facilities, not informing or "cleaning-up" after recreationists, nor otherwise managing recreational use. To a large extent, management costs are determined by management objectives in so far as they specify acceptable impact parameters and management supplied services. Total management costs are therefore a function of management parameters and amenity use levels.

## 3.5 Individuals' costs

Those people who (potentially) gain benefits from a resource incur costs from a variety of sources. People not wishing to use a resource, but who obtain benefits from knowledge of its existence may incur costs in order to obtain knowledge about the resource. Costs may be incurred before any use takes place if potential users incur expenses, or effort, in obtaining rights to use a resource. For example, costs may be incurred in attempting to secure reservations at a campground even though those efforts are unsuccessful. The type of use allocation system imposed by management will clearly affect the nature and magnitude of such costs (Shelby and Danley, 1979).

Actual use may create transportation, gear, and opportunity costs as well as direct costs imposed through site entrance and facility user fees (Walsh, 1986). Walsh indicates that the two most important costs associated with outdoor recreation are the money costs of travel and the time costs of travel and site use. In both cases these costs arise because of the opportunities foregone by their use in this activity. Money could be used to produce other types of benefits, and time could be spent in other pursuits, including work and leisure.

## 3.6 Actual versus measured impacts

Shelby and Colvin (1982) have shown that the number of contacts actually occurring, the number measured by researchers, and the number perceived by users can differ. Changes in management will be reflected in changes in actual contacts.

However, Manning (1986:73) indicates that it is the "visitors perceived reality" that influences satisfaction, a view supported by the empirical evidence of Chambers and Price (1986). Regardless of whether user welfare is a function of actual or perceived contacts, if researchers estimate welfare as a function of researcher measured contacts, and these are different from actual and/or perceived contacts, the underlying relationship may not be well represented by the researcher's models. It is possible that existing relationships will not be identified by researchers. Consequently, such models are unlikely to be capable of identifying optimal use levels.

Different methods of measuring satisfaction are reported to provide inconsistent results (Manning, 1986:75-76). It is unclear which is the correct way to measure the benefits of a recreation experience, leading Manning to suggest the need for consistency of measurement technique to allow inter-temporal and inter-site comparisons to be made.

Recent evidence (Anderson and Kanters, 1988) reveals that recreator reports on use levels are likely to be grossly inaccurate, suggesting that researcher information on use levels is more appropriately obtained by independent methods such as traffic counts and entrance records, wherever possible.

The differences between perceived and researcher measured variables are not important in conceptual models which seek only to identify the underlying relationships which determine the outcomes of the recreation experience for recreationists. These differences do, however, become important when those relationships are subject to empirical modelling, especially if those models are to be used as a basis for making management decisions. Clearly, the existence of measurement problems for so many of the key variables in existing models could easily hide important relationships.

## 3.7 Displacement

Displacement is the result of dissatisfaction arising from unrealised expectations (Becker, 1981). As long as people learn from their experiences, it is apparent that expectations will change when impacts (manageable or non-manageable) differ from expectations of those impacts - at least in the long run[8]. Each visit to the backcountry provides recreationists with more information on which to base expectations. Since expectations of impact parameters are important in determining individual use it is apparent that changes in expectations may cause changes in use. When changes result in individuals reducing or discontinuing use those people are said to have been displaced. Displacement may therefore be modelled as a result of changed expectations, which arise from changes in perceptions of impact parameters.

## 3.8 Partial/general equilibrium

Management objectives may be specified for a single resource (site), or for a whole series of sites, or in terms of aggregate social welfare obtained from use of all resources. In many cases it is likely that management actions at one site will cause price changes at others. Similarly, displacement may cause changes in the nature of the experience at substitute sites. In these cases, total social welfare impacts can only be evaluated by comparing the changes in benefits at all sites at which prices and/or congestion effects change (Just, Hueth and Schmitz, 1982).

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[8] Expectations may change [illegible] other than experience. For example, information supplied by management, friends, [illegible] may also be important influences on expectations of impact parameters at the site [illegible] and at other sites.

Analyses which look only at the impacts on an individual site are termed <u>partial equilibrium</u> studies, while those that account for interaction effects are termed <u>general equilibrium</u> studies. Partial equilibrium models require that data need be collected for only one site, and far less modelling is involved. While general equilibrium studies are the conceptually correct approach in most instances, review of recreation studies reveals that partial equilibrium studies are the norm.

Even if management objectives are specified in terms of the benefits from a single site, interaction effects are important. Actions at the target site may induce price changes at other sites. Since demand for any good is a function of all prices (amongst other things), such price changes can feed back to the original site, resulting in shifts in demand for that site. For example, imposition of an entrance fee to visit an uncongested public forest makes use of other recreation facilities relatively more attractive and may result in many recreationists transferring their use to a neighbouring private forest. In other words, demand for the private forest increases as a result of an increase in price at the public forest. If the private operator responds to this increase in demand by increasing the price for use of the private forest, the public forest will become relatively more attractive. Demand for the public forest will increase. This process may proceed through several cycles, until some equilibrium is reached, or may go on indefinitely. Benefits of use of the public site (at the high price) would therefore be somewhat higher after the price of use of the private forest was increased. Hence, even if management objectives are specified for only a single site, a general equilibrium model may be needed to make optimal management decisions.

In many cases inaccuracies which result from use of partial equilibrium studies are expected to be minor, encouraging use of this more simple approach. Often a facility has either no close substitutes, or very many close substitutes. In either case, management of the site in question has little, if any, impact on substitute prices, implying that partial equilibrium analysis is appropriate. Further, because backcountry recreation is so widespread, management actions at one site are unlikely to change input prices. For example, a complete ban on use of any single national park would be most unlikely to affect the price of camping equipment because many recreators would recreate elsewhere, and those who did not would probably constitute an insignificant proportion of the total market for camping gear. In many instances the price of inputs (e.g. fuel, one of the most important inputs to outdoor recreation (Walsh, 1986)) is determined on international markets, reducing further the probability of management actions at any one site affecting input prices.

A further situation in which partial equilibrium models are acceptable is when there are no congestion effects and prices of substitute facilities are held constant. This is expected to be true of many publicly provided outdoor recreation facilities, where fees are fixed for particular types of facility, or there are no fees. When congestion is present, partial equilibrium models are acceptable in those cases in which displacement occurs into uncongested areas in which the addition of the displaced users does not push site use above congestion thresholds. In these cases neither price nor the quality of the experience at the substitute site change.

General equilibrium effects can be modelled by recognising that management parameters, including constraints to use, of one site effect impact parameters at other sites. Consequently, expectations of impact parameters at other sites change, resulting in a revised set of individual demands for all sites.

## 3.9 Revised carrying capacity model

The elements identified in the preceding sections are now incorporated into a more complete model for carrying capacity determination, extending the contributions from Shelby and Manning. The model is illustrated in Figure 10. The objective of the revised carrying capacity model is to maximise social benefits, which are specified in some management objective (or social welfare) function. Definition of social benefits may be provided by government or managerial decree, or through some form of aggregation of individual welfares.

The variables which can be controlled by facility managers include: management imposed constraints to use, other management parameters, recreationists' expectations (via control of information - a management parameter), and the behaviour of users (through education and regulation - also management parameters). Altering any of these variables has the potential to alter use levels, impact parameters, and hence social benefits. Derivation of the actual use level was discussed in an earlier section. The number of interparty contacts, categorised by where, when, and with whom they occur, is influenced by use levels, topography, and other management parameters. Other management parameters include factors such as: number of trail miles, number of trail intersections, restrictions on direction of travel, restrictions on campsite location, and so on. The actual levels of other impact parameters (e.g. trail condition and wildlife populations) are influenced by actual use levels (by category), other management parameters (e.g. trail maintenance), and non-manageable impacts, including weather, insect populations, etc.

Individuals, who may be users or non-users, are unlikely to notice all impacts, and those noticed may not be perfectly perceived. Therefore, perceptions of impact parameters are likely to be different from actual values. It is on these

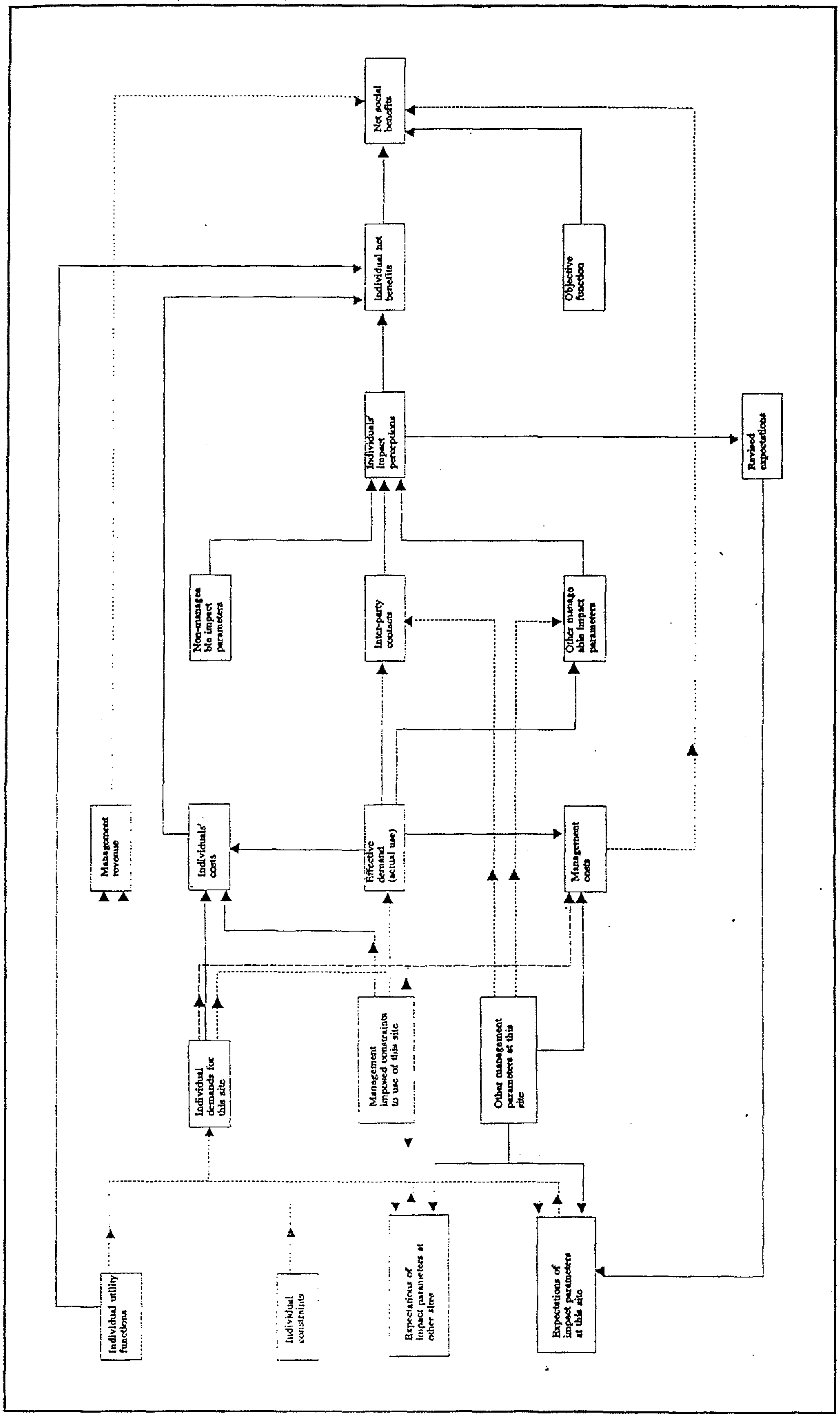


**Figure 10** Revised carrying capacity model

perceptions that individuals judge the (gross) value of their experience, or the resource, and revise expectations of impact parameters for the future. Net individual benefits are influenced by gross individual benefits and individual costs. Social benefits are a function of individual (user and non-user) benefits and management costs.

While these elements are sufficient to outline a conceptual model of benefits arising from backcountry recreation, it is important to incorporate the likely differences which are caused by measurement errors if the model is to be used for management in a practical setting. Important discrepancies may occur in measurement of impact parameters, and in measures of individual and social benefits.

## 3.10 Summary

This chapter has adapted existing carrying capacity models to develop a more conceptually sound model. Existing models were found to be deficient in several important areas, including definition of objectives and the nature of factors influencing demand.

In the next chapter the model developed in Figure 10 will be used to identify aspects of the resource management process to which resource economics can be applied, and interactions within the model will be structured in economic models. The model developed in Figure 10 serves as a reminder of the simplifications embodied in economic models of sub-sections of the recreation system.

# CHAPTER FOUR

# ECONOMIC MODELS OF CONGESTION

## 4.1 Introduction

Goods may be categorised on a spectrum from private to public. Pure private goods can bestow benefits only upon the person possessing them. The pure private good owner has the ability to costlessly exclude others from possession of the good. In a world consisting only of pure private goods, which are tradeable without transaction costs, (perfect markets) a Pareto optimal outcome is automatically achieved by the actions of selfish individuals. At the other end of the spectrum are pure public goods. These goods are capable of bestowing benefits on many people simultaneously. The amount of use (or level of benefits obtained) by one person does not affect anyone else's ability to use (or the level of individual benefits obtained from use of) the good. It is not possible to exclude anyone from using a pure public good. Because of their non-excludable nature, there is little incentive for private provision of pure public goods. A major role of government is to coercively tax people to provide public goods. Public goods supplied by government in this way include: the legal system, defence, health services, transportation services, and preserved natural areas.

Most goods do not fit either of these extreme cases. Exclusion is possible, but only at some cost to the excluder. Transactions are not costless, and externalities exist. Congestion is one form of externality. It is a situation where individuals are affected by the actions of others without being able to influence those actions directly. In the simplest case it is not the specific activities undertaken by others which degrade the experience, but simply the number of other participants in an activity. Individuals may become congested by others pursuing the same activity as themselves (i.e. too many skiers on the mountain), or by those pursuing other activities (powerboats detracting from sailboaters experiences), or a combination of the two. Inter-activity congestion is often referred to as conflict.

## 4.2 The economic model

The simplest case to model consists of a fixed size facility catering for a single activity which is susceptible to in-group congestion. Examples of such cases would be downhill ski areas and art galleries which cater for only one activity, but in each case the enjoyment of the experience is strongly influenced by the number of other users of the facility. At ski fields tow queues become longer and there is more risk of collision on the slopes, while at art galleries it becomes more difficult to obtain an unobstructed view as numbers of participants increase. The following analysis draws heavily upon the theoretical foundations laid by Dorfman (1984), but builds upon them to analyse the distribution of benefits, inter-activity congestion and efficiency of alternative allocation methods.

The net benefit any individual gains from use of a facility is determined, *inter alia*, by the number of other users, the amount of use made by the individual, and the cost (to the individual) of use. This information is summarised in the individual's demand curve. When expressing demand in two-dimensional price-quantity space it is necessary to draw a family of demand curves to represent how the individual is affected by the amount of use others make of the facility. Each of these curves is a *constant crowding demand curve* (Dorfman, 1984) - it expresses how much use the individual would make of a facility at any price, for a given level of use by others.

Individuals demand a level of use of the congestible facility ($x_i$) which is dependent upon the price of use (p) and the amount of use by others (X), holding other prices, income, etc. constant.

$$x_i = f^i(p,X) \tag{4.1}$$

Equation 4.1 is the individual's demand function for the congestible facility. Equation 4.1 is a constant crowding demand function whenever X is fixed. Demand functions for non-congestible goods are special cases of Equation 4.1 in which $\delta f^i/\delta X=0$ for all X. In that case the demand function is simply the familiar $x_i = d^i(p)$.

Total use is the sum of use by all individuals.

$$X^d = \sum_i x_i = F(p,X) \tag{4.2}$$

Equation 4.2 is the aggregate demand function. As with the individual case, the aggregate demand function may be expressed in price-quantity space by fixing X at a constant level, thereby defining an aggregate constant crowding demand function. It is also possible to express price, or marginal willingness to pay, as a function of use parameters - the inverse of Equation 4.2.

$$p = \phi(X^d,X) \qquad \phi_1 < 0,\ \phi_2 < 0 \tag{4.3}$$

Only when $X^d$ is equal to X are expectations fully satisfied, a necessary condition for equilibrium. Substituting the equilibrium condition in Equation 4.3 yields the inverse market demand function (Equation 4.4a) and the market demand function (Equation 4.4b).

$$p = \phi(X,X) = \Theta(X) \qquad 4.4a$$

$$X = G(p) \qquad 4.4b$$

Although it is a simple relationship between price and quantity, the market demand function is determined by the crowding-dependent demand function[1]. Moreover, for common demand specifications the two types of demand function will have the same specification, linear crowding-dependent inverse demand functions, for example, imply linear inverse market demand functions (Table 2).

When price is used to ration use, equilibrium use level is determined from the market demand function. Consumers' surplus benefits equal the area beneath the constant crowding demand curve corresponding to the current level of use, above the price charged.

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[1] The introduction of the notion that contacts, rather than use level, are important in determining benefits does not alter the concept of constant crowding demand curves. With contacts:

Marginal benefits = A(c,Q) where c is number of contacts, and Q is level of use demanded.

But, the number of contacts is influenced by the number of people on site:

c = f(k) where k is actual level of use (effective demand).

Therefore,

A = A(f(k),Q)
= B(k,Q), as before.

The equilibrium condition is k = Q.

We now have the concept of a constant contact demand curve. Since the number of contacts (however defined) may be greater or less than total use (multiple and zero contacts with other users are possible), it is not possible to determine the relative locations of the constant crowding and constant contact demand curves a priori. If resource users are well informed and there is no uncertainty in the relationship between use level and contacts, knowledge of total use (k) determines number of contacts (c), and either k or c may be used in analysis. i.e.

A(c,Q) = B(k,Q).

Analysis will proceed using the actual level of use as the independent parameter of the demand relationship, recognising that this may be interpreted at any point as the number of contacts.

**Table 2** Inverse demand specifications

| Crowding-dependent inverse demand specification | Market inverse demand specification |
|---|---|
| $\phi = a+bQ+ck$ | $\Theta = a+(b+c)Q$ |
| $\phi = a+b.\log(Q)+c.\log(k)$ | $\Theta = a+(b+c).\log Q$ |
| $\log(\phi) = a+bQ+ck$ | $\log(\Theta) = a+(b+c)Q$ |
| $\log(\phi) = a+b.\log(Q)+c.\log(k)$ | $\log(\Theta) = a+(b+c).\log Q$ |
| $\phi = a+bQ^{-1}+ck^{-1}$ | $\Theta = a+(b+c)Q^{-1}$ |
| $\phi = a+\sum(b_iQ^i+c_ik^i)$ | $\Theta = a+\sum(b_i+c_i)Q^i$ |

Figure 11 depicts the two types of demand curve and their relationship. At price $p^*$ the equilibrium level of use is $X^*$. Rent accruing to the resource owner is Area A, and consumers' surplus is Area B. As others have indicated (e.g. Anderson, 1980; McConnell, 1980), the area beneath the market demand curve (Area A plus Area B plus Area C) provides an overestimate of total benefits obtained from use of a congestible good (Area A plus Area B).

Benefits from use of congestible facilities fall into two categories; those accruing to resource owners or managers, and those accruing to resource users. The first category is termed producer's surplus, rent, or profits. It is equal to the difference between revenue earned and costs incurred by the manager. The second category of benefits is termed consumers' surplus, which is equal to the total benefits accruing to consumers less the costs of use incurred by users. Total benefits from resource use are equal to the sum of these two benefit types, in the absence of externalities which affect the welfare of those who do not use or manage the resource. In the absence of management costs, the different categories of benefit may be expressed mathematically as:

$$\text{Rent} \equiv R = X.p \qquad 4.5$$

$$= X.\Theta(X)$$

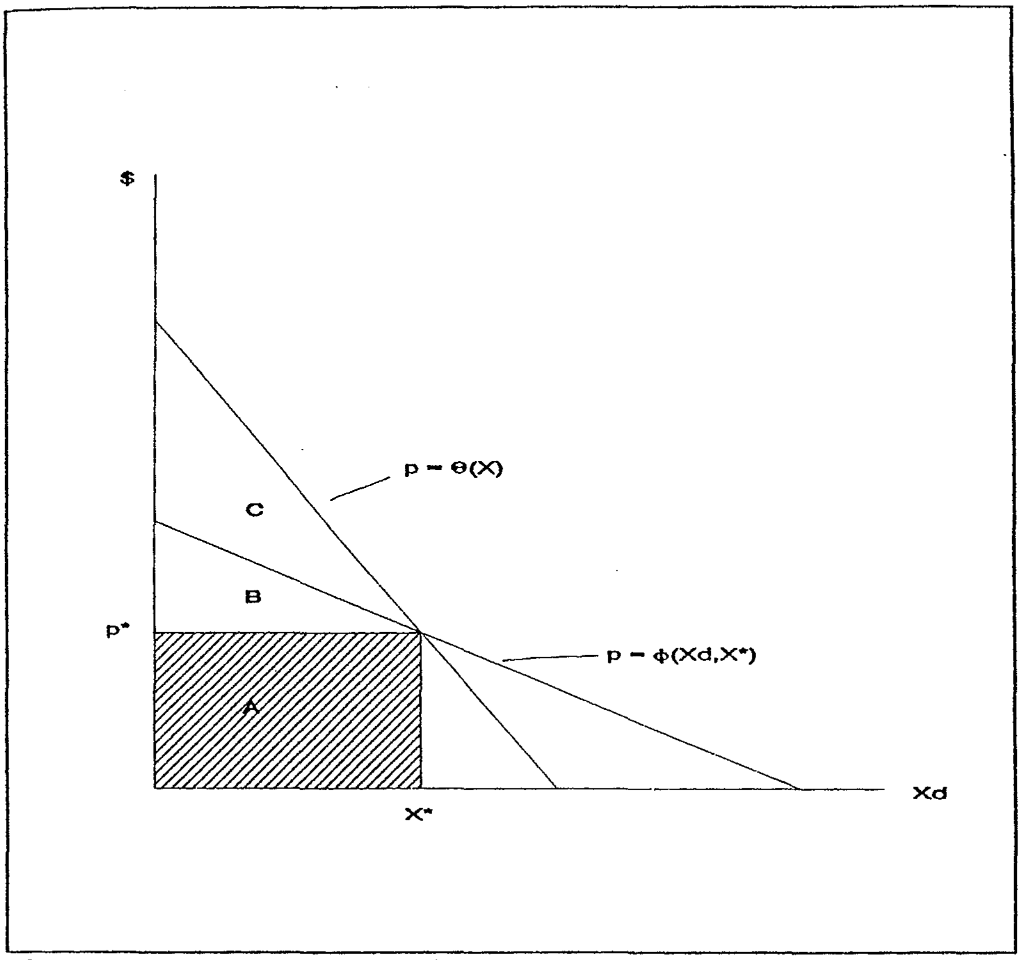


**Figure 11** Market and constant crowding demand curves.

$= G(p).p$ where $G(p)$ is the inverse market demand curve.

$$\text{Total benefits} \equiv B = \int_0^X \phi(X^d,X)dX^d \quad \text{where } X = G(p) \tag{4.6}$$

$$\begin{aligned}\text{Consumers' surplus} \equiv CS &= \int_0^X [\phi(X^d,X) - p]dX^d \\ &= \int_0^X \phi(X^d,X)dX^d - X.\Theta(X) \\ &= B-R\end{aligned} \tag{4.7}$$

While aggregate measures of benefit are likely to be of interest to managers (for example, in determining efficient use levels and the revenue implications of price rationing), per-capita measures are likely to be more important for individual resource users. It is these measures which, to a large extent, determine the popularity and/or acceptability of management programmes. Consumers are likely to be interested in their expected utility levels for alternative management approaches. Some per-capita measures which may be important are:

(i) mean consumer surplus per open access unit of use[2] (Equation 4.8),

(ii) mean consumer surplus per actual unit of use with rationing in place (Equation 4.9), and

(iii) mean consumer surplus per potential unit of use at the rationed level of use (Equation 4.10).

| | | |
|---|---|---|
| $CS_a = CS.[G(p=0)]^{-1}$ | where G is the market demand function. | 4.8 |
| $CS_b = CS.[X^R]^{-1}$ | where $X^R$ is the rationed use level. | 4.9 |
| $CS_c = CS.[F(p=0,X^R)]^{-1}$ | where F is the aggregate constant crowding demand function for use level $X^R$. | 4.10 |

## 4.3 The supply side

Supply costs are important determinants of supplier behaviour and of total benefits obtained from resource use. Producer's surplus is the level of net revenue accruing to the supplier after deduction of supply costs.

---

2 Care must be taken to differentiate between number of users and number of units of use. For some facilities these two measures will be nearly identical (for facilities which one would only expect to use once during the relevant time period, e.g. annual visits to the Grand Canyon by New Zealanders). By choosing a short enough period, the two measures may always be made to coincide. For many practical situations this will not be possible. Expressing benefits on a per capita basis will require information on the distribution of (potential) use across the (potential) user population. Equations 4.8 to 4.10 are therefore expressed in terms of units of use.

Producer's surplus $\equiv$ PS = p.X - TC(X)

where TC(X) is the total cost of supplying X units of the activity.

For a social optimum total producer's surplus plus total consumers' surplus must be maximised. A necessary condition[3] for a social optimum is Equation 4.11 (Dorfman's condition 2).

$$\phi(X^*,X^*) + \int_0^{X^*} \phi_2(X^d,X^*)dX^d - MC(X^*) = 0 \qquad 4.11$$

where MC(X) is marginal cost of supplying unit X.

Equation 4.11 has a straightforward interpretation. The benefits accruing to the marginal user plus the change in benefits to intra-marginal users because of increased congestion must equal the marginal costs of supplying an extra unit of use for a social optimum. In the absence of congestion effects $\phi_2 = 0$ and Equation 4.11 reduces to the standard result, price equals marginal cost.

A non-discriminating, profit-maximising, monopolist will allow the amount of use which equates marginal revenue (evaluated on the market demand curve) to the monopolist's marginal costs (Equation 4.12).

$$\begin{aligned} MC(X) &= p + X.[dp/dX] \qquad 4.12 \\ &= \phi(X,X) + X.[\phi_1(X,X) + \phi_2(X,X)] \end{aligned}$$

---

3 Second-order conditions must also be met.

Comparison of Equations 4.11 and 4.12 indicates that monopoly supply will be socially optimal only if Equation 4.13 is satisfied.

$$\int_0^X \phi_2(X^d,X)dX^d = X.[\phi_1(X,X) + \phi_2(X,X)] \qquad 4.13$$

This expression may be interpreted as stating that for monopoly to be efficient there must be an X such that the total cost to infra-marginal resource users of a marginal change in number of users is equal to the reduction in rent the monopolist receives from infra-marginal users with a marginal change in number of users. Equation 4.13 is different from Dorfman's condition for efficiency of monopoly (Dorfman, 1984: p.96). Dorfman fails to account for the equilibrium condition in determining the total derivative of price with respect to number of users. Dorfman interprets dp/dX to be $\delta p/\delta X$. This is incorrect because of the interaction between $X^d$ and X, which must be equal at equilibrium. Therefore:

$$\frac{dp}{dX} = \frac{\partial\phi}{\partial X^d}.\frac{\partial X^d}{\partial X} + \frac{\partial\phi}{\partial X}$$

$$= \phi_1 + \phi_2 \qquad \text{since} \quad \frac{\partial Xd}{\partial X} = 1$$

A change in X causes two effects. First, it shifts the constant crowding demand curve ($\phi_2$), affecting the willingness to pay of the marginal user. Second, it is necessary to change price ($\phi_1$) to influence the marginal resource user's participation decision, that is, to change $X^d$ so that it remains equal to X.

Equation 4.13 is not satisfied for all demand specifications, but could be satisfied by many demand specifications. A special case occurs when $\phi$ is constant with respect to $X^d$, that is, the constant crowding demand curves are parallel to each other and horizontal. As Dorfman (1984) indicates, no consumers' surplus is obtained, total benefit is simply producer's surplus, and maximisation of producer's surplus will therefore maximise total benefits. Note that when this particular case is satisfied $\phi_1=0$ and Dorfman's condition for the optimality of monopoly is correct, but only as a special case of Equation 4.13.

Equation 4.11 identifies what is commonly referred to as the *efficient* use level. The efficient use level maximises use benefits to society. Some of those benefits are in the form of rent, and some are consumers' surplus. However, efficiency maximisation may not be the sole objective of management. For example, a non-discriminating monopolist may wish to maximise revenue or rent obtained from a resource. Alternatively, it may be wished to maximise benefits obtained by resource users (consumers' surplus).

The condition for consumers' surplus maximisation are identified by differentiating Equation 4.7 with respect to X and invoking the equilibrium condition, yielding Equation 4.13. Therefore, when Equation 4.13 is satisfied monopoly is efficient <u>and</u> maximises the benefits accruing to resource users. In this case, monopoly control of congestible resources is efficient and is in the best interest of consumers.

For many demand specifications, Equation 4.13 will have no solution, or will result in a minimum at $X=0$. In these cases consumers' surplus is maximised when use is maximised, i.e. when price is zero. Inspection of Equation 4.13 indicates that very few functions will result in internal maxima. In these cases the open access situation yields the greatest aggregate surplus *to users*. While a reduction in use may increase total benefits, this will be at the cost of consumers' surplus - assuming that prices are used to limit use.

## 4.4 A simple example

The linear case illustrates the findings of the previous sections.

Let $\phi = a + bX^d + cX$ , and therefore $\Theta = a + (b+c)X$

Assuming, for simplicity, that there are no supply costs and solving Equations 4.11 to 4.13 yields the following necessary conditions for optimality:

| | |
|---|---|
| Total benefits are maximised when: | $X = -a/(b+2c)$ |
| Producer's surplus is maximised when: | $X = -a/[2(b+c)]$ |
| Consumers' surplus is maximised when: | $-bX = 0$ |

The first two conditions satisfy second order criteria and illustrate that, with linear constant crowding demand curves, monopoly supply is sub-optimal unless $b=0$. The consumers' surplus condition is satisfied when $b=0$ (the special case of horizontal constant crowding demand curves), in which case there is no consumers' surplus implying that any X maximises consumers' surplus. If $b \neq 0$ then X must equal zero to satisfy the condition for maximum consumers' surplus, but this fails to satisfy the second order condition and yields a minimum. For the linear case, consumers' surplus is maximised when use is maximised, i.e. there is a corner solution which is satisfied when $\phi(X,X)=0$. Solving this expression identifies the condition for maximisation of consumers' surplus with linear constant crowding demand curves, i.e. consumers' surplus is maximised when $X = -a/(b+c)$.

In the linear case where prices are used to ration use the optimal level of use differs for each objective, i.e.

$X_{\text{maximum PS}} < X_{\text{maximum B}} < X_{\text{maximum CS}} = X_{\text{open access}}$

## 4.5 More than one type of use

Let there be two types of use (activities), X and Y, each of which is subject to both inter and intra-group congestion. The inverse constant crowding demand functions for X and Y are $\phi$ and $\psi$ respectively. Marginal use benefits (marginal willingness to pay) are determined by the actual amount of the use in question ($X^d$ or $Y^d$) and by the total amount *of each type of use expected* (X and Y).

$$\phi = \phi(X^d, X, Y) \qquad \phi_i < 0 \qquad \forall i$$

$$\psi = \psi(Y^d, X, Y) \qquad \psi_i < 0 \qquad \forall i$$

Benefits are maximised when $X^*$ and $Y^*$ are chosen to satisfy conditions 4.14 and 4.15 (assuming an internal solution).

$$\frac{\partial B}{\partial X} = \phi(X^*, X^*, Y^*) + \int_0^{X^*} \phi_2(\bullet) dX^d + \int_0^{Y^*} \psi_2(\bullet) dY^d - MC(X^*) = 0 \qquad 4.14$$

$$\frac{\partial B}{\partial Y} = \psi(Y^*, X^*, Y^*) + \int_0^{X^*} \phi_3(\bullet) dX^d + \int_0^{Y^*} \psi_3(\bullet) dY^d - MC(Y^*) = 0$$

When selfish individuals have open access to a congestible facility for which no fee is charged, they will choose levels of use ($X^a$ and $Y^a$) to satisfy conditions 4.16 and 4.17 when they perceive the level of the other activity to be parametric ($X^b$ and $Y^b$).

$$\phi(X^a, X^a, Y^b) = 0 \qquad 4.16$$

$$\psi(Y^a,X^b,Y^a) = 0 \qquad 4.17$$

At equilibrium all expectations are satisfied, implying that Equations 4.16 and 4.17 cannot hold simultaneously, resulting in the final outcome of Equations 4.18 and 4.19.

$$\phi(X^c,X^c,Y^c) = 0 \qquad 4.18$$

$$\psi(Y^c,X^c,Y^c) = 0 \qquad 4.19$$

Comparison of Equations 4.14 and 4.15 with Equations 4.18 and 4.19 leads to the conclusion that: if the resource is not managed, users of each type will demand more than the efficient level of use for the level of the other activity. This situation is conceptually similar to two fleets exploiting a single fishery (Anderson, 1986: pp.189-191), and may be analysed by a similar reaction-function approach. Three equilibrium outcomes are possible: activities X and Y can coexist, activity X occurs (no activity Y), activity Y occurs (no activity X). As with the fishery case, both activities may need to be managed to ensure an efficient resource allocation.

## 4.6 A more general approach

The preceeding section has addressed the allocation of a resource assuming that both activities occur throughout the management unit. Special case outcomes occur when the efficient amount of one type of activity is zero. In that case the management problem reduces to identifying the optimal amount of a single activity.

A more general problem concerns allocation of the resource amongst different use types. That is, some of the resource may be allocated <u>only</u> to activity X, some <u>only</u> to activity Y, and some to <u>both</u> activities X and Y. The management problem then becomes one of identifying (i) how much of the resource to allocate to each activity type, and (ii) how much of each activity should be permitted in each type of area. If pricing is to be used as the rationing method, the second management problem can be viewed alternatively as identifying the optimal price to charge in each type of area.

The complete set of resource allocation options is presented in Figure 12.

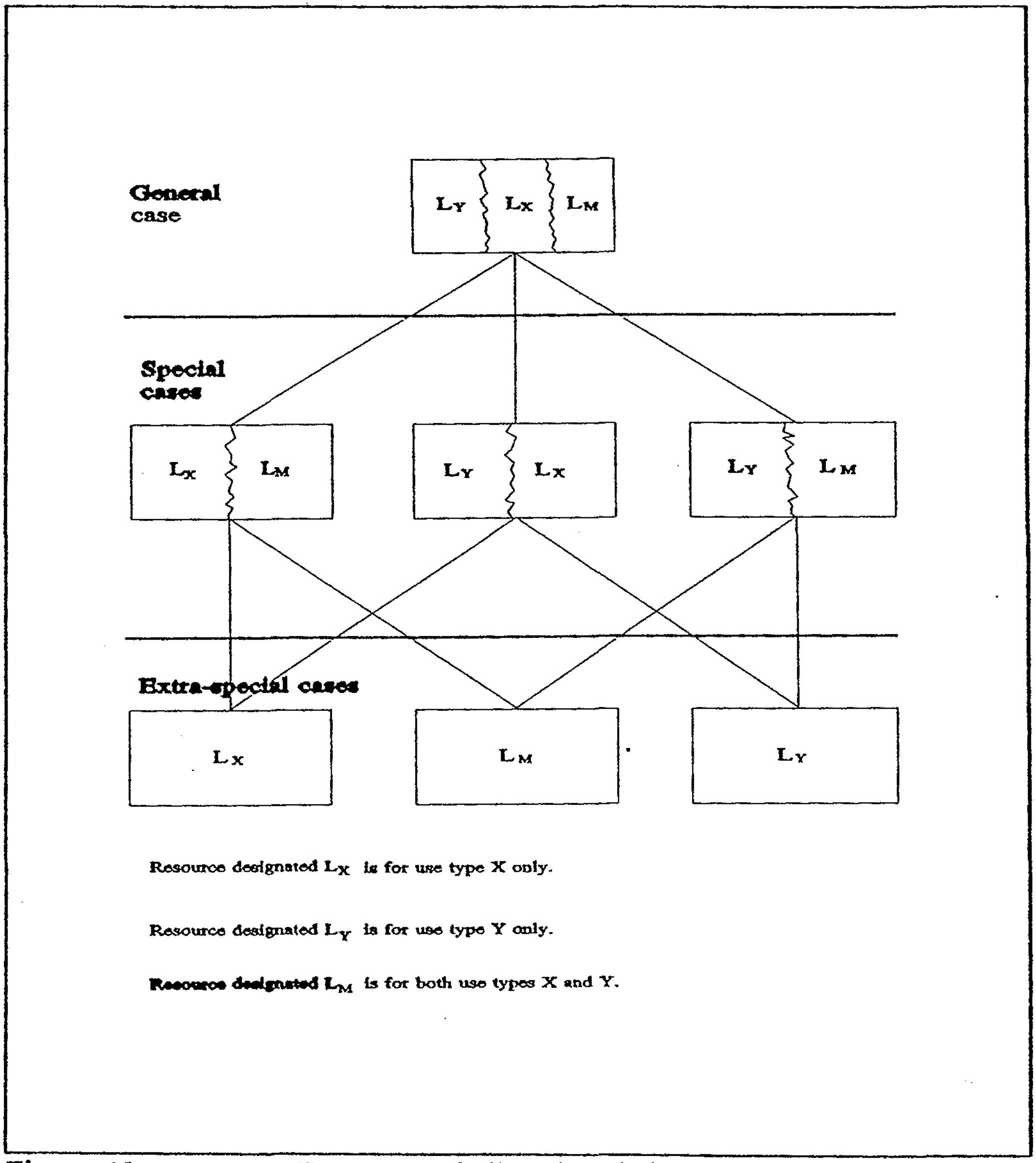


Figure 12 Taxonomy of allocation choices.

The ragged lines within the boxes indicate non-fixed boundaries of choice. While the total amount of resource is fixed, the amount allocated to each type of use is a choice. The most general problem is to decide how much resource to allocate to each type of use (X, Y, and mixed). Special case outcomes occur when only two types of area are permitted. Extra-special cases occur when only one type of use is permitted. By definition, the efficient solution to the general case can be no less efficient than the efficient solution to any special case, which can in turn be no less efficient than the efficient solution to any associated extra-special case.

For simplicity, assume there are no management or transaction costs. Total benefits are then simply the sum of consumer surplus and rent across all use area types. Let the quantities of the two activities be X and Y in the single-activity areas, and x and y in the mixed-activity area. Define the inverse demand functions for each area type as:

Activity X only area: $\alpha = \alpha(X^d, E^X, e^x, e^y, p_M)$

Activity Y only area: $\beta = \beta(Y^d, E^Y, e^x, e^y, p_M)$

Inverse demand functions for the area allowing both activities X and Y are:

(i) Activity X: $\gamma = \gamma(x^d, E^X, e^x, e^y, p_W)$

(ii) Activity Y: $\epsilon = \epsilon(y^d, E^Y, e^x, e^y, p_Y)$

where;

| | | |
|---|---|---|
| $E^X$ | = | The expected density of type X recreators in the area allowing only activity X |
| $E^Y$ | = | The expected density of type Y recreators in the area allowing only activity Y |
| $e^x$ | = | The expected density of type X recreators in the area allowing both activities W and Y |
| $e^y$ | = | The expected density of type Y recreators in the area allowing both activities X and Y |
| $X^d$ | = | The actual amount of use by type X recreators in the area allowing only activity X |
| $Y^d$ | = | The actual amount of use by type Y recreators in the area allowing only activity Y |
| $x^d$ | = | The actual amount of use by type W recreators in the area allowing both activities X and Y |
| $y^d$ | = | The actual amount of use by type Y recreators in the area allowing both activities X and Y |

$p_M$ = The price of access to the area allowing both activities X and Y
$p_X$ = The price of access to the area allowing only activity X
$p_Y$ = The price of access to the area allowing only activity Y

Total value of the resource is then:

$$V = \int_0^X \alpha(\bullet)dX^d + \int_0^Y \beta(\bullet)dY^d + \int_0^x \gamma(\bullet)dx^d + \int_0^y \varepsilon(\bullet)dy^d \qquad 4.20$$

$$= V_1 + V_2 + V_3 + V_4$$

The allocation problem is to find the optimal distribution of the resource to each of the three uses, subject to the constraint on resource availability, i.e.;

$$L_X + L_Y + L_M \leq L$$

where;

$L_X$ = amount of resource allocated to activity X only

$L_Y$ = amount of resource allocated to activity Y only

$L_M$ = amount of resource allocated to both activities X and Y

$L$ = total amount of resource available

The numbers of facility users may be controlled directly (i.e. X, Y, x and y are the choice variables) or indirectly via prices ($p_X$, $p_Y$, and $p_M$ are the choice variables. Since use levels are determined by price, optimisation of either leads to the same solution. For convenience, optimality conditions are determined for the direct control case here.

The Lagrangian is:

$$F(X,Y,x,y,L_X,L_Y,L_M,\lambda) = V_1+V_2+V_3+V_4 - \lambda(L_X+L_Y+L_M - L)$$

First order, necessary conditions for an internal maximum are:

$$\frac{\partial F}{\partial X} = \alpha(\cdot) + \int_0^X \frac{\partial \alpha(\cdot)}{\partial X} dX^d + \frac{\partial V_2}{\partial X} + \frac{\partial V_3}{\partial X} + \frac{\partial V_4}{\partial X} = 0 \tag{4.21}$$

$$\frac{\partial F}{\partial Y} = \beta(\cdot) + \int_0^Y \frac{\partial \beta(\cdot)}{\partial Y} dY^d + \frac{\partial V_1}{\partial Y} + \frac{\partial V_3}{\partial Y} + \frac{\partial V_4}{\partial Y} = 0 \tag{4.22}$$

$$\frac{\partial F}{\partial x} = \gamma(\cdot) + \int_0^x \frac{\partial \gamma(\cdot)}{\partial x} dx^d + \frac{\partial V_1}{\partial x} + \frac{\partial V_2}{\partial x} + \frac{\partial V_4}{\partial x} = 0 \tag{4.23}$$

$$\frac{\partial F}{\partial y} = \epsilon(\cdot) + \int_0^y \frac{\partial \epsilon(\cdot)}{\partial y} dy^d + \frac{\partial V_1}{\partial y} + \frac{\partial V_2}{\partial y} + \frac{\partial V_3}{\partial y} = 0 \tag{4.24}$$

$$\frac{\partial F}{\partial L_i} = \frac{\partial V}{\partial L_i} - \lambda = 0 \qquad \forall i,\ i \in (X,Y,M) \tag{4.25}$$

$$\frac{\partial F}{\partial \lambda} = L_X + L_Y + L_M - L = 0 \tag{4.26}$$

$\lambda$ is the marginal value of the resource. If use of the resource is not controlled only the first terms in Equations 4.21-4.24 will be considered by individuals. Only Equations 4.23 and 4.24 would be considered if the resource was not allocated to separate use areas, resulting in satisfaction of Equations 4.18 and 4.19 which were shown to be inefficient. The potential gains from adopting a resource allocation/use rationing scheme are found by comparing the total benefits under the alternative scenarios. Rationing would incur positive transaction costs, which would have to be considered to determine the efficiency and/or profitability of rationing.

## 4.7 Introducing time: paths to equilibrium

Following the analysis of Wilman *et al.* (1987) it is possible to construct functions which describe how different types of user change their levels of use of a resource in response to the conditions encountered during use. Conditions include management parameters and the number of each type of user - either encountered, or in total[4].

Suppose that there are two activities[5] taking place at a resource. Resource users participating in each activity use the number of participants in each activity (x and y), as well as the vector of management parameters (**m**), to evaluate their recreational experiences. Let decisions about future use be based upon existing conditions, then these relationships may be expressed as:

$$\frac{dy}{dt} = f(x,y,\mathbf{m}) \qquad 4.27$$

$$\frac{dx}{dt} = g(x,y,\mathbf{m}) \qquad 4.28$$

Assume decreasing marginal benefits of encountering other users engaged in either activity. Then,

$$\delta f/\delta x < 0, \ \ \delta f/\delta y < 0, \ \ \delta g/\delta x < 0, \text{ and } \ \delta g/\delta y < 0 \qquad 4.29$$

As the number of participants in any activity increases, resource users (who, by Equation 4.29, are assumed to be crowd-averse) feel more crowded.

---

4 In many instances it is possible that use levels will affect environmental conditions, affecting future use and non-use benefits obtained from the resource, consequently affecting future resource use rates. Such problems require solution by dynamic optimisation methods, such as optimal control. For simplicity, the current analysis is restricted to the direct inter-personal impacts of use levels in a comparative-static framework.

5 Each a distinct type of activity (e.g. swimmers and powerboaters), or may be undertaking variants of the same activity (e.g. fly anglers and spin fishers).

Consequently, the rate of increase of use declines, and eventually becomes negative. Given a constant level of one activity (say x, so that x=k) and constant management parameters, the level of the other activity will remain static at the point where dy/dt=0. Setting Equations 4.27 and 4.28 equal to zero and solving each for y yields Equations 4.30 and 4.31.

$$y = F(x,m) \qquad 4.30$$

$$y = G(x,m) \; [\text{or} \quad x = H(y,m)] \qquad 4.31$$

Equations 4.30 and 4.31 indicate the levels of each activity, at equilibrium for that activity, for any *given* level of the other activity. Condition 4.29 indicates that:

(i) the partial derivatives of F and G with respect to x will each be negative,

(ii) dy/dt will be negative above the line y=F(x,m),

(iii) dx/dt will be negative above the line y=G(x,m).

An internal equilibrium (one in which both x and y are positive) can only exist if there is a solution to Equation 4.32, so that dy/dt and dx/dt are simultaneously zero.

$$F(x,m) = G(x,m) \qquad 4.32$$

Assuming *some* use will be made of the resource, four possible cases exist.

(1) $x > 0, \; y > 0$
(2) $x = 0, \; y > 0$
(3) $x > 0, \; y = 0$
(4) $x = 0$ and $y > 0$ <u>or</u> $x > 0$ and $y = 0$

These are the open-access outcomes that Anderson (1986:189) describes for a two-fleet fishery. The four cases are illustrated in the phase diagrams of Figures

13 to 16. The arrows indicate the directions of change of x and y in each sector of each figure. For example, at Point A in Figure 13 $dy/dt<0$ and $dx/dt<0$, so both x and y will decrease. At Point B $dx/dt<0$ and $dy/dt>0$, so x will decrease and y will increase.

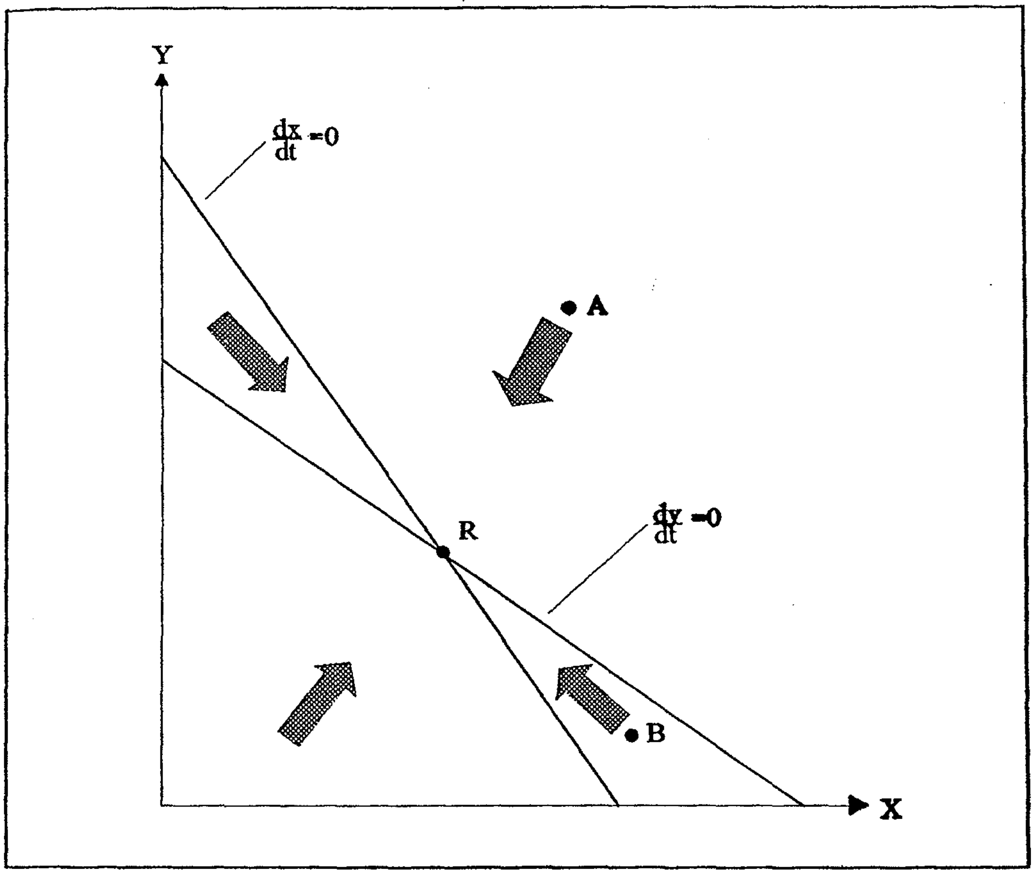


**Figure 13** Equilibrium, case 1.

In Case 1 both activities are represented. A stable equilibrium occurs at Point R. In Cases 2 and 3 only one activity occurs at equilibrium. In Case 2 the activity occurring is activity y (Point S), and in Case 3 the activity occurring is activity x (Point T). Case 4 refers to an unstable saddle-point, where Equation 4.32 is potentially satisfiable at Point U. Any deviation from Point U will drive the system to one of Points V or W, depending upon the direction of the initial perturbation.

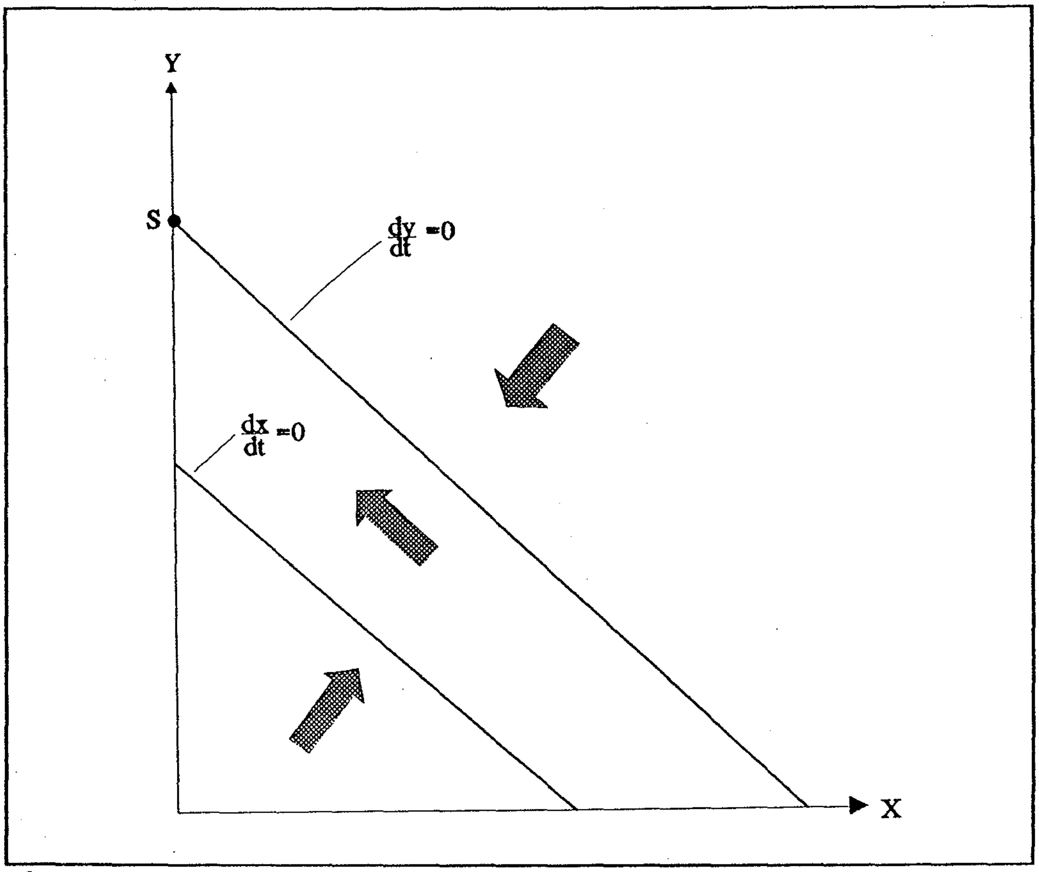


**Figure 14** Equilibrium, case 2.

These results are positive. That is, they describe how a system will behave. To determine desirable, or normative, outcomes it is necessary to introduce values representing the desirability of different outcomes. Section 4.5 showed that, when desirability is measured in terms of efficiency, too much of each type of activity will take place for the level of the other activity. That is, normative versions of Equations 4.30 and 4.31 (on social efficiency criteria) will be closer to the origin than the positive versions, i.e.,

$$y^{*} = F^{*}(x,m) < y = F(x,m) \quad 4.33$$

$$y^{*} = G^{*}(x,m) < y = G(x,m) \quad 4.34$$

where, the * superscript indicates an optimal (normative), but unknown relationship.

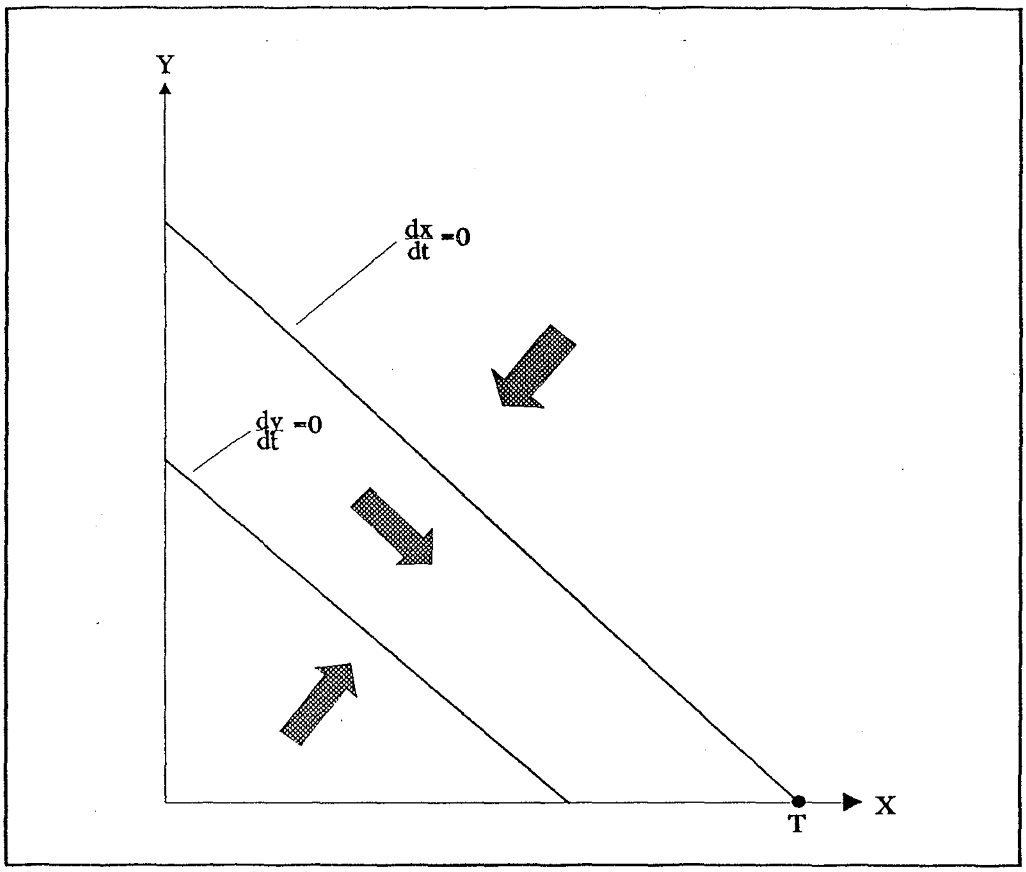


**Figure 15** Equilibrium, case 3.

The socially efficient outcome is found by solving Equations 4.14 and 4.15. Because the differences between positive and normative reaction functions are not necessarily proportional for the different activities, the socially efficient amount of any activity could be greater than, equal to, or less than the naturally occurring level. However, it is clear that for the two, congestible activity case the socially efficient outcome will not entail an increase in the levels of both activities.

## 4.8 Displacement

A common characteristic of outdoor recreation is the displacement of one group of users by another. Displacement can result in the same activity being pursued, but by a different group of people, as crowd-tolerant individuals replace crowd-averse individuals. At a conceptual level, it is conceivable that the disutility

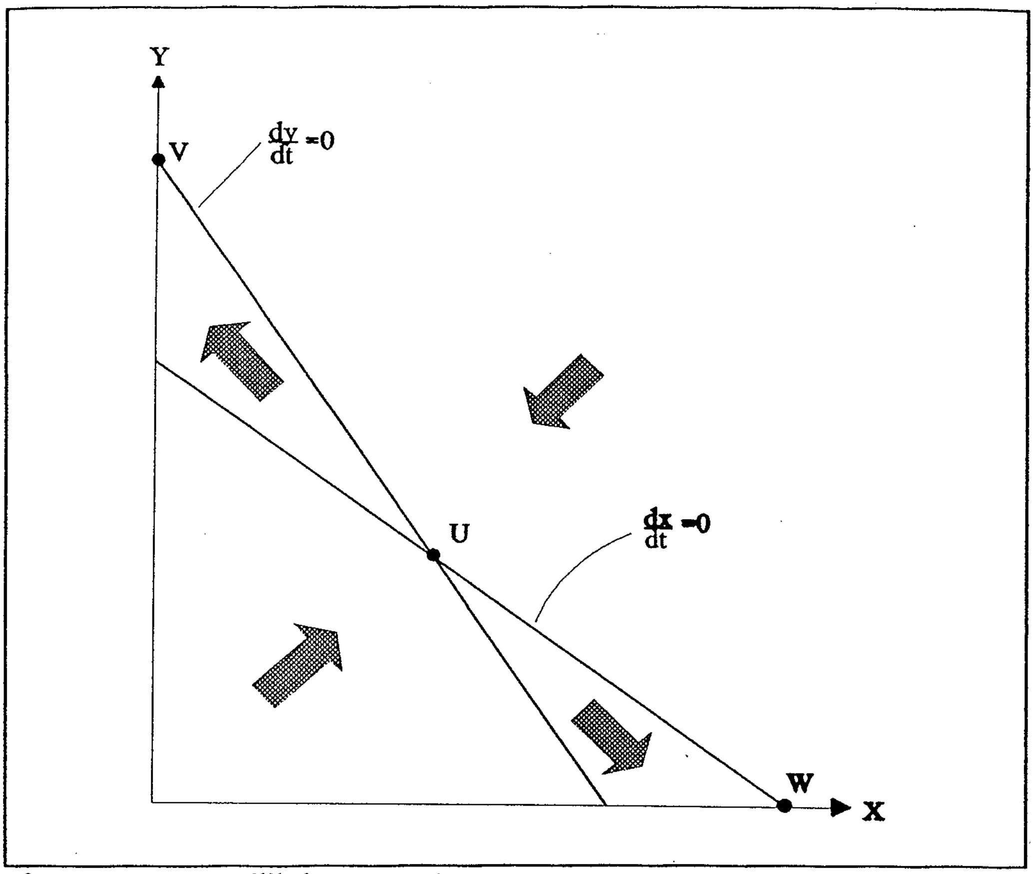


**Figure 16** Equilibrium, case 4.

to those who have been displaced may outweigh the utility gained by the displacers. Displacement may occur because of an autonomous increase in user numbers, in which case the more crowd-averse may choose to recreate elsewhere, while the more crowd-tolerant continue use of the original facility. Alternatively, changes in management parameters could influence user groups in different ways. Provision of high quality mountain huts, for example, may cause increased use of the backcountry by youth groups. This increase in use may be sufficient to cause those seeking solitude to recreate elsewhere. Clearly, the two causes of displacement are not unrelated - as at least one management parameter, the amount of facility use permitted, influences user numbers directly.

Figures 17 and 18 present a simple example of the displacement process. Suppose there are two types of resource user. One type (y) is crowd-averse, and

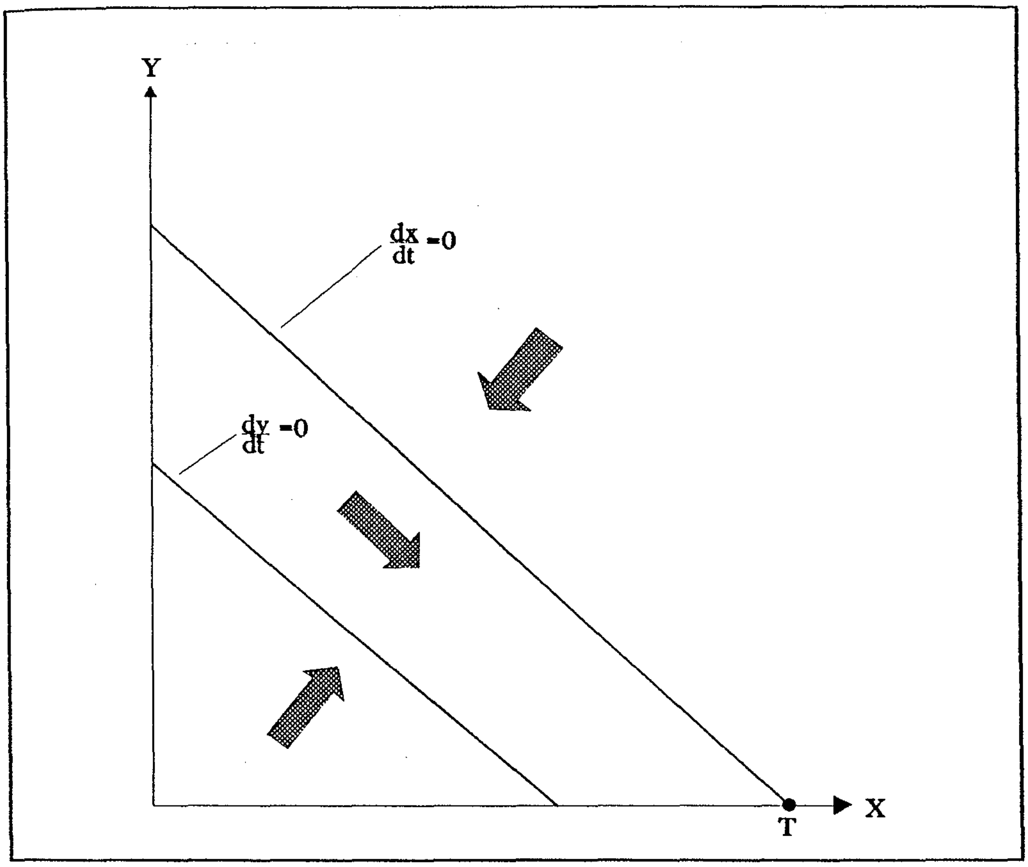


Figure 17 Before displacement.

one type (x) is crowd-neutral. Given the existing numbers in each group, a stable equilibrium occurs at Point C in Figure 17. Now, assume that for some reason, the potential number of crowd-neutral users increases over time (from $x_1$ to $x_2$ in Figure 18), while the potential number of crowd averse users stays constant. With activity x occurring at level $x_2$, $dy/dt<0$ for all positive y. Equilibrium moves to Point D in Figure 18. There is no longer any use by type y users. Type y users have been displaced by type x users.

This outcome may not be desirable. If society places a high value on use y relative to use x[6], there may be benefits from controlling use. This is exactly the same as the more general problem described earlier, however, it does highlight one

[6] This may occur for utilitarian reasons. For example, the aggregate willingness to pay of type y resource users in the initial state may be greater than the aggregate willingness to pay of type x resource users in the final (type y users displaced) state.

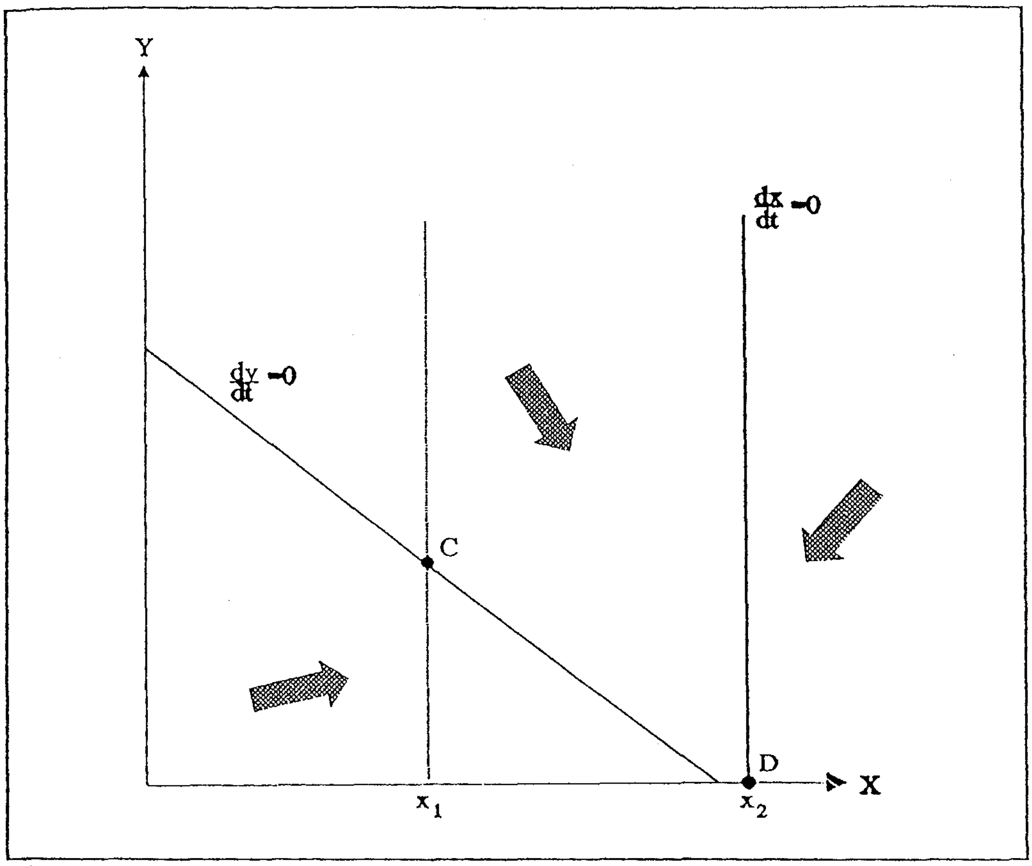


**Figure 18** Use type y displaced.

important point. Given that outcomes are determined by the *potential* number of users of each type, management cannot limit their concerns to those currently using the resource. Some users who could potentially derive high benefits from use of a resource may already be displaced, or currently represent only a small proportion of total use. All demands on the resource must be considered to identify the opportunity costs of management.

## 4.9 Characteristics approach to demand modelling

Explanation of recreation behaviours is provided by Lancaster's demand theory (Lancaster, 1966a, 1966b, 1971) which is based on demands for characteristics, rather than demands for goods *per se* in the usual economic demand model (the "goods approach"). The demands for goods and activities are derived demands, in response to the characteristics delivered by them. Consumers "produce" bundles of desired characteristics by combining "inputs" of goods to produce activities. For example; time, motorised transport, walking, the natural environment and camping equipment are all inputs to the activity "tramping", which delivers characteristics such as solitude, appreciation of nature and physical challenge.

The "characteristics approach" has been employed to model demand for natural resources. Morey (1981) used a model closely based on the characteristics approach to explain distribution of skiers across 15 Colorado ski areas. Greig (1983) applied the approach to a group of Australian ski areas in order to illustrate the procedural possibilities and was able to model demand and welfare changes contingent upon changes in characteristics of the ski areas.

Each good or activity can be described in terms of the characteristics it possesses. For example, a mountain climb could be described in terms of its scenic, botanic, wildlife, technical challenge, physical challenge, and social characteristics. Different climbs may provide these characteristics in different proportions, or at different costs. Other activities will also be able to provide some, or all, of these characteristics.

The characteristics approach to demand modelling has an advantage over the goods approach in that it allows explanation of the complementarity and substitutability of goods. That is, it provides explanation of why people commonly consider hiking and mountain climbing to be close substitutes, while viewing both as very different to an activity such as stamp collecting. The characteristics approach allows prediction of behaviour when new goods are introduced, or when new or improved information on the characteristics of existing goods is received.

This latter aspect allows the theory to explain the displacement and rationalisation processes.

Lancaster originally used the term "satisfactions", but adopted the term "characteristics" because of "its normative neutrality ... satisfactions ... has too many connotations" (Lancaster, 1966b:14). The theory may be considered a formalisation of the multiple satisfactions concept, and is consistent with discrepancy theory[7]

The following discussion is based on a simple graphical description of the characteristics approach, other sources describe its mathematical content (see, for example; Greig, 1983; Bockstael and McConnell, 1983). The purpose of this section is simply to explain the processes observed to occur because of increases in user density and to provide an economic explanation of those processes. Mathematics is necessary only if one desires to estimate actual demand changes or welfare impacts. Without wishing to discount the mathematical content of this model, the graphical approach is adopted as the simplest heuristic for explanation of the displacement and rationalisation processes.

Assume, for simplicity, that consumers have only three goods available to them (say; wilderness, remote areas, and walkways). Each of these goods has two characteristics, scenic beauty and solitude, but these are delivered in different proportions for each of the three goods[8]. Wilderness provides the most solitude per unit of scenic beauty, and walkways the least. These proportions are indicated by the rays in Figure 19.

---

[7] The multiple satisfactions concept and discrepancy theory are both discussed in Chapter 2.

[8] Most goods and activities will actually embody many characteristics. See, for example, Manfredo, Driver and Brown (1983) for some of the characteristics output from outdoor recreation activities. By limiting analysis to two characteristics graphical analysis is possible. No substance is lost by this simplification.

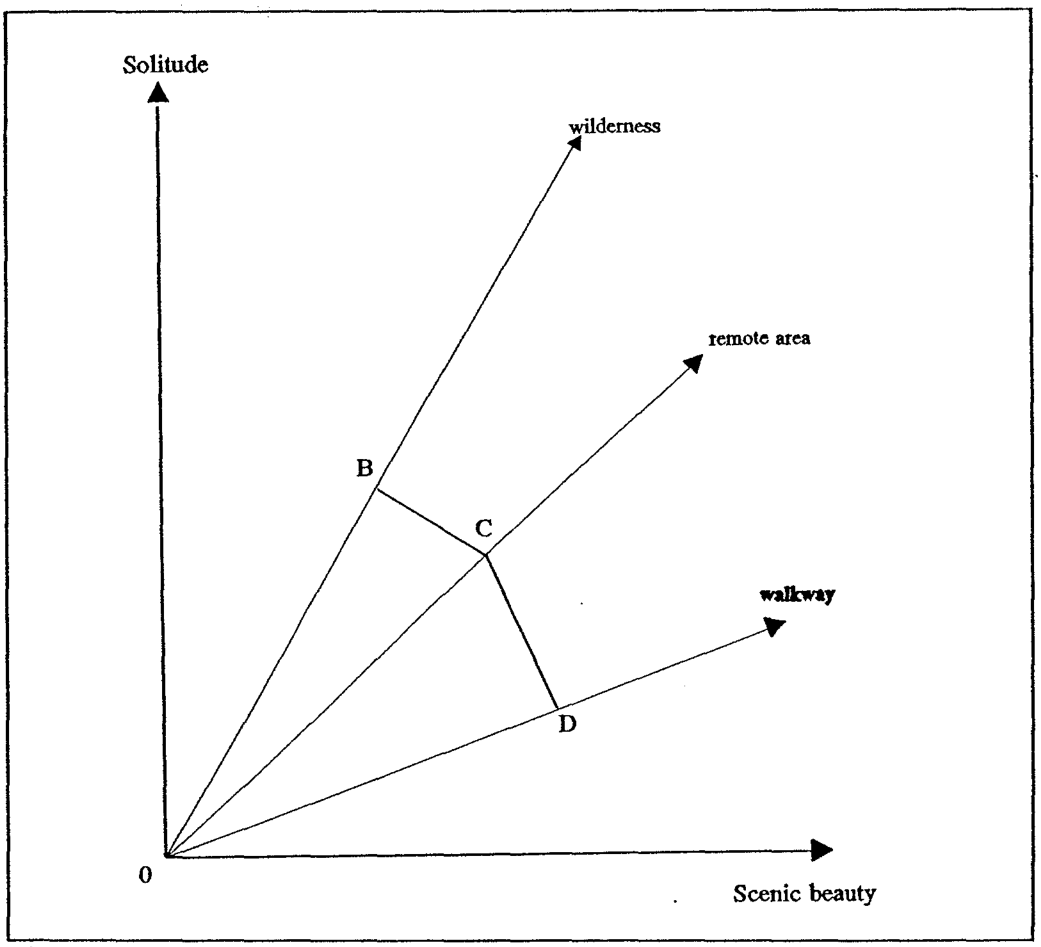


**Figure 19** Characteristics rays.

The consumer's budget and the prices of goods jointly determine combinations of characteristics which fall within the consumer's budget set. If all of the budget were spent on wilderness characteristics combination B in Figure 19 would be obtained. Similarly, combinations C and D could be obtained by spending all the budget on either of the other goods. Consumers have the ability to purchase combinations of goods, therefore linear combinations of points B, C and D are available within the consumer's budget, resulting in a characteristics possibility set defined by area OBCD (not all the budget need be spent)[9].

[9] Note that prices determine which goods or activities are relevant to the characteristics possibility set. If, for example, the price of remote area use was extremely high consumers would not purchase trips to remote areas since they could obtain the same characteristics combinations more cheaply by purchasing a combination of trips to walkways and wilderness. The characteristics possibility set is therefore always a concave set. See Lancaster (1966a) for explanation.

Characteristics are delivered in fixed proportions with constant returns, implying that if twice as much of a good is obtained the quantity of each characteristic received will be doubled. Lancaster's description of this approach to demand modelling implicitly assumes that all consumers face identical prices, and explicitly assumes that the characteristics of each good are objective and are perceived identically by all individuals. These assumptions ensure that all individuals face identically shaped characteristics possibility sets. These sets will differ in scale, however, according to the individual's budget.

Since the price of using recreational facilities is often largely composed of travel expenses, the spatial distribution of recreational facility users implies that prices will vary amongst potential facility users. Further, individuals may have incorrect expectations regarding impact parameters, and may therefore believe that facilities provide characteristics in different proportions to those actually delivered. Different individual perceptions and prices imply that each individual faces unique perceived and actual characteristics possibility sets. Breaking Lancaster's fixed price and objective characteristics proportions assumptions allows better explanation of individual behaviours, without altering the essential nature of the approach. Each individual will face a characteristics possibility set determined by the prices faced by them, their individual budget, and their perception of characteristics embodied in goods.

Consumers have indifference curves described in terms of characteristics. These indifference curves reflect the consumer's tastes, and conform with all the assumptions in the goods approach to demand modelling (Lancaster, 1971; Varian, 1978). Assuming that more solitude and/or scenic beauty is preferred to less (*ceteris paribus*) implies that indifference curves are convex. Individuals may "view" the merits of characteristics differently, implying that each individual has a unique set of indifference curves representing their personal tastes. Welfare-maximising consumers will attempt to attain the highest indifference curve allowed by their budget set. Figure 20 illustrates the recreator's choice.

Given tastes (represented by indifference curves) and constraints (indicated by the budget set), the best thing the recreator can do is purchase characteristics combination G. To obtain this combination a mixture of wilderness and remote

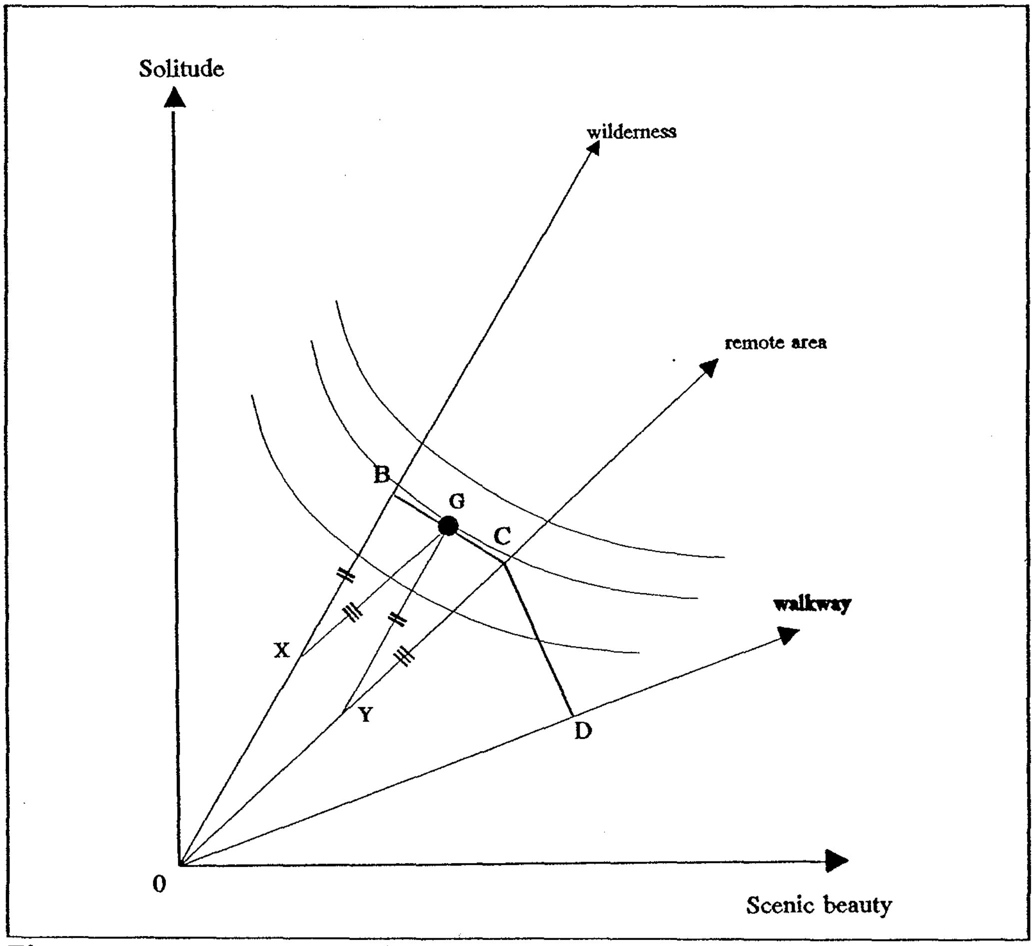


**Figure 20** Consumer choice in characteristics space.

area hiking will be purchased[10]. By geometry it is possible to ascertain that the fraction of the recreator's budget spent on wilderness hiking will be OX/OB (= YC/OC), with the fraction OY/OC (= XB/OB) being spent on remote area hiking. Demand for a good (use of a recreational facility) is therefore dependent on the consumer's tastes (utility function defined in characteristics space), expectations of characteristic proportions for this and other goods (characteristics rays, alternatively impact parameters in Shelby's terminology), prices, and budget and other constraints faced by the individual.

Lancaster assumes that characteristics of goods are fixed through time. He treats the introduction of a new good as the introduction of a new bundle of characteristics. A new good is represented by an additional ray, which will alter the individual's characteristics possibility set if the new good's price is sufficiently low.

When a good is changed in some way, it displays new characteristics (for example, increased trail maintenance makes walking easier but probably does not affect aesthetic beauty or other hiking characteristics). Such changes may be analysed by introducing a new good with the revised characteristics, and removing the old good from the consumers' choice set. In terms of Figure 19, the characteristics ray for the altered good rotates about the origin.

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[10] Note that the consumer only consumes two of the three goods on offer. In general, the number of goods consumed will be less than or equal to the number of characteristics. In the case where the characteristics possibility frontier (BCD in Figure 4.10) is a straight line through three or more rays (or an n-dimensional plane through more than n rays) the consumer's optimal choice is indeterminate. For example, if BCD in Figure 4.10 were a straight line, the optimal characteristics combination could be achieved by choosing any one of an infinite number of combinations of the three goods.

## 4.10 Displacement revisited

Suppose there are two wilderness areas offering very similar combinations of characteristics, Wilderness A and Wilderness B. Wilderness A is much cheaper to use (it may be extremely close to the wilderness user population, reducing transportation costs, or a lower admission fee may be charged there). The consumer choice is illustrated in Figure 21. Suppose there are two types of wilderness user, one type values solitude relatively highly (Loners), while the other type is less concerned with the presence of others and values solitude relatively

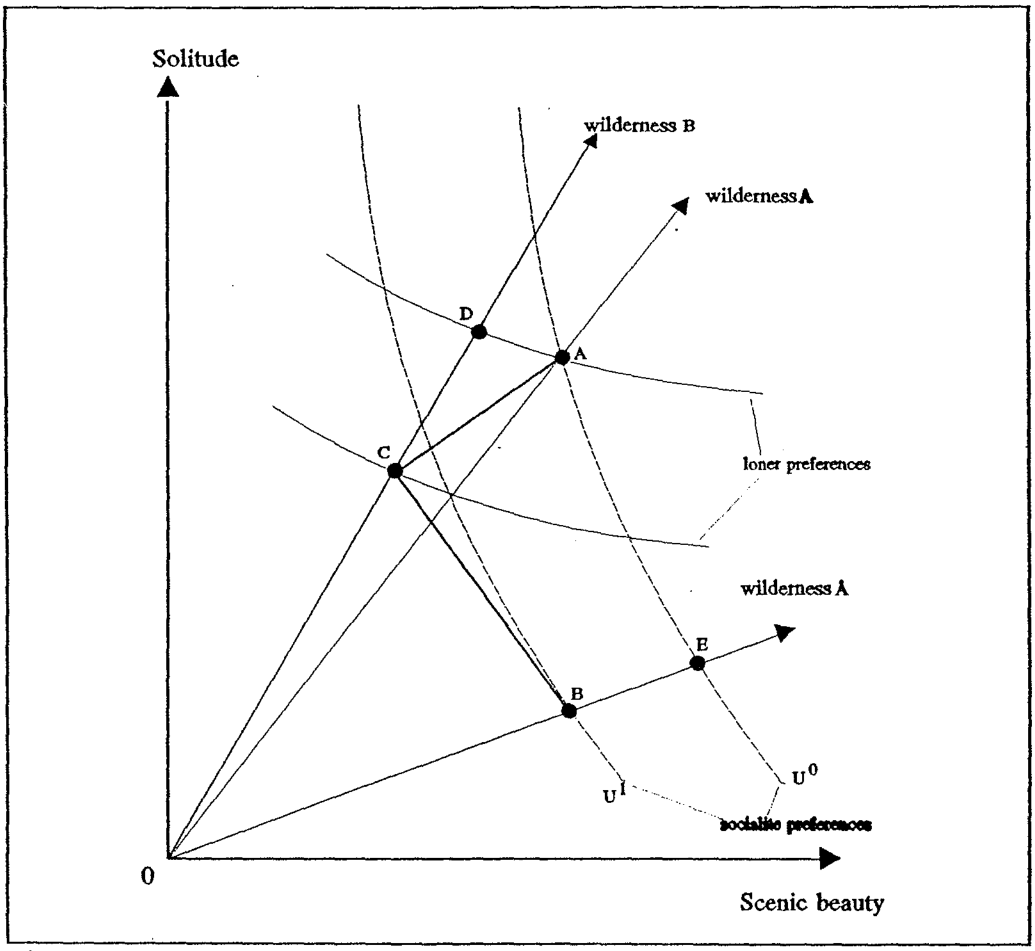


**Figure 21** Displacement

lowly (Socialites). Given the preferences illustrated in Figure 21, both types of wilderness user choose to use only Wilderness A[11].

Assume that over time there is increased recreational use of wilderness areas in general (perhaps population grows). If all of the expansion of wilderness use was channelled into Wilderness A it would no longer deliver characteristics in the same proportions as before. For the same amount of scenic beauty, less solitude is available because user density has increased. The characteristics proportion ray labelled Wilderness A no longer exists. It has been replaced by the ray labelled Wilderness Â. Point B[12] is the bundle of characteristics now received if all the budget is spent on use of Wilderness A.

The characteristics possibility set for an individual recreator, formerly area OCA, is now area OCB. Consumers are no longer able to purchase characteristics combination A. Socialites will continue to spend all of their budget on visiting Wilderness A, and so will use Wilderness A at the same level as before (Point B). However, they do not gain the same level of utility as before the increase in use since they are now only able to reach indifference curve $U^1$, but were previously

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[11] To the individual solitude is parametric, while to society it is endogenous. Each individual is concerned with the density of other resource users. Whatever use the individual makes of the facility, the density of others does not change. The individual's decision affects others, however, because it affects the density of other users they encounter. Other users' characteristics proportions rays therefore rotate because of this individual's decision. If any one individual chooses to increase their use of a congestible facility the characteristics proportion rays of all other individuals (and the aggregate market) rotate away from the solitude axis, and vice versa. Consequently, the graphical form of analysis of the characteristics approach to aggregate demand modelling for congestible resources is impractical.

Since the slope of the characteristics proportion ray for a congestible good is a function of the total number of purchases of that good, the slope (alternatively the coefficient on the solitude/crowding characteristic) is a function of all parameters determining use, such as: price, income, population size, and population preferences. Consequently, Figure 4.11 illustrates the *status quo*. The characteristics proportion ray "Wilderness A" shows the proportion in which characteristics are delivered with current preferences, incomes, and prices.

[12] Since scenic beauty at Wilderness A is unchanged, Point B is found where the perpendicular from Point A intersects characteristics ray Â.

able to reach $U^0$. Loners now find that their best choice (Point C) is to pay the extra unit costs for using Wilderness B and recreate solely in that area[13].

Loners have been displaced (either partially or fully) from Wilderness A and their level of welfare has decreased from the initial situation. In the situation depicted in Figure 21, each Loner would need to have income increased by a factor of (OD)/(OC) to attain their initial welfare level with the new characteristics proportions[14].

This example represents a vast simplification of reality where there are many characteristics, many substitute goods and a large range of preferences, but is sufficient to illustrate the displacement process. By definition, Wilderness Â has higher user density than Wilderness A. Since all Loners now use Wilderness B, all use of Wilderness Â is by Socialites. Therefore, the composition of the user group at Wilderness A has changed. Socialites have displaced Loners. Displacement is a process which distributes congestion (and other undesireable impacts) amongst sites and user groups.

An increase in use need not displace users only toward goods offering relatively more solitude. Consider the situation illustrated in Figure 22. There are now three wilderness areas, however Wilderness C offers relatively little solitude. As before, Wilderness A becomes more used, and the proportion of characteristics

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13 Note that as Loners transfer their use from Wilderness A to Wilderness B the characteristics proportions ray for Wilderness Â will rotate counter-clockwise. This rotation will continue until all Loners are using Wilderness B, or the characteristics possibility frontier is tangent to the Loner's indifference curve at Point C. Figure 4.11 presents the former, final-state case.

14 The increase in income by a factor of (OD)/(OC) represents the loner's compensating variation. Therefore it is tempting to think that, if indifference curves in characteristics space can be estimated, it would be possible to employ benefit-cost analysis to determine the optimal levels of facility use by different types of user. However, as use of Wilderness B increases the characteristics combination offered by Wilderness B will change. The characteristics approach does not, therefore, provide a simple means of estimating welfare change. Further discussion on this topic is reserved until Chapter 7.

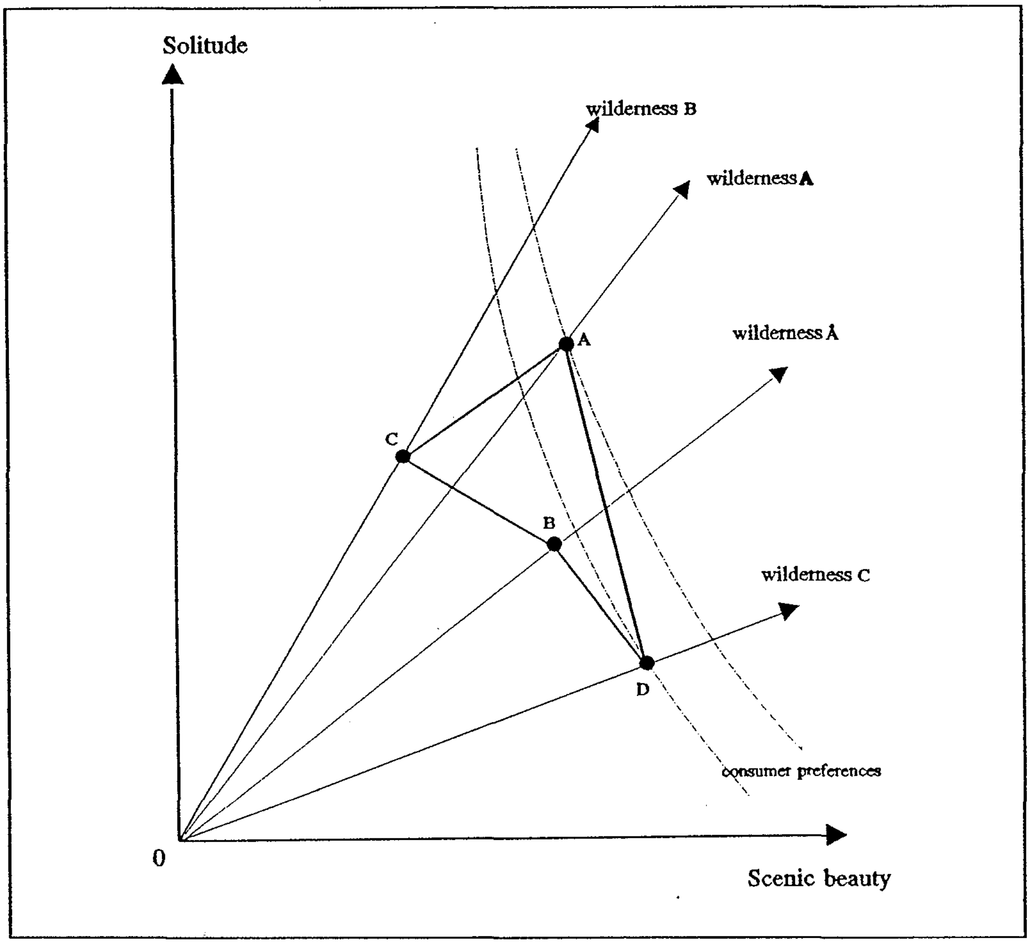


**Figure 22** Displacement to more crowded areas

obtainable changes to that illustrated by the ray labelled Wilderness Â. The budget set alters from area OCAD to area OCBD, inducing consumption of characteristics combination D. Given the new budget set, consumers have decided that it is worthwhile to accept gains in scenic beauty at the expense of some loss in solitude[15].

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[15] The loss in solitude will be more pronounced than indicated as the characteristics proportion ray for Wilderness C rotates clockwise with additional use of Wilderness C. The key point is that <u>some</u> use of Wilderness A is transferred to Wilderness C, even though Wilderness C is more crowded then Wilderness A.

## 4.11 Rationalisation

It should be noted that, while the Socialites of Figure 21 continue use of Wilderness A, they suffer a loss in welfare because of the alteration in proportions in which characteristics are delivered (an increase in income by a factor (OE)/(OB) would allow a Socialite to reattain his/her initial utility). The only users who do not suffer any welfare loss are those for whom solitude is not a parameter in the utility function, or for whom increased solitude brings disutility (those with vertical or positively sloping indifference curves). Because characteristics are delivered in different proportions than originally, those Socialites who have experienced both levels of use have seen a product shift. The outcomes from a trip to Wilderness A are different to those originally experienced. That this product shift is recognised by Socialites, yet they still consider that use of Wilderness A is their best option, is the essence of the rationalisation hypothesis.

The rationalisation process implies that managers should not use the justification that site users are "satisfied" to ignore the impacts of changes. It is apparent that even if facility users claim to be satisfied, they will not be "as satisfied" as before the product shift if their indifference curves are negatively sloping.

## 4.12 Conclusions

Many analyses of carrying capacity determination and the impacts of increased user density have taken effective demand to be the independent variable and individual satisfaction as the dependent variable (Manning, 1986). Such approaches are too narrow to maximise social welfare because they ignore the distributional nature of management objective functions. In many instances it is important to know who is being satisfied, who is not, and to what degree. Such approaches also fail to integrate evaluation of the outcomes with the underlying motivations for engaging in the activity. Consequently, they do not satisfactorily explain recreationist responses to changes in the nature of the experience, nor do they provide a sound conceptual basis on which to judge the welfare impacts of changes in user density.

Demand modelling clarifies these deficiencies by providing a sound conceptual basis for the displacement and rationalisation processes. Displacement and rationalisation result in welfare losses for both former and current resource users (as long as they do not prefer greater user densities), so should not be overlooked in determining management strategies. They imply that the preferences of all potential resource users should be considered, and that management policies which aim to provide conditions in which individual users are satisfied do not maximise the benefits obtainable from a recreational facility.

Modelling demand by characteristics also allows the prediction of behaviours of sub-groups of resource users contingent upon management changes, and is therefore useful in identifying the distributional and social justice implications of alternative courses of action.

Estimation of the welfare impacts of changes in price or permitted use levels of congestible (and other) goods is complicated by changes in these parameters causing changes in characteristics coefficients. Simple graphical models are not sophisticated enough to deal with this complication. However, extension of the constant crowding demand curve model provided by Dorfman, or mathematical modelling of the characteristics approach have the ability to overcome this problem.

Guidance on the efficiency of alternative management programmes may be provided if it is possible to estimate monetary measures of value for changes in management parameters. The economic theories analysed in this chapter provide a conceptual framework which can be used to estimate value. To obtain such estimates it is first necessary to be able to estimate demand for characteristics or demand for congestible goods themselves. Neither of these tasks is likely to be straightforward and consequently discussion of approaches to valuation is reserved for Chapter 7.

The economic models of this chapter are necessarily simplifications of reality. Further, they are simplifications of the model built in Chapter 3 and illustrated in Figure 10. The normal goods approach to demand modelling adopted by Dorfman and extended here deals with only a sub-set of the variables in Figure 10. The variables entering these models are illustrated by the bold boxes in Figure 23. The normal boxes are important aspects, but are not allowed to vary in the models investigated here, they are part of the *ceteris paribus* assumption. For example, individual utility functions are important determinants of individual net benefits, but in these demand models are considered constant and exogenous. The heavy dashed lines of Figure 23 illustrate the links from the actual level of use to individual benefits and revised expectations. There is no theoretical reason that the links through inter-party contacts and impact perceptions could not be incorporated (see Footnote 1 in this chapter), however, practical measurement problems appear to be large (Shelby and Colvin, 1982) and these links have been ignored in economic models to date.

The box with double bold borders represents the variable (management parameter) of interest and under control of management. In dealing with congestion problems by rationing use, managers must choose what constraints to

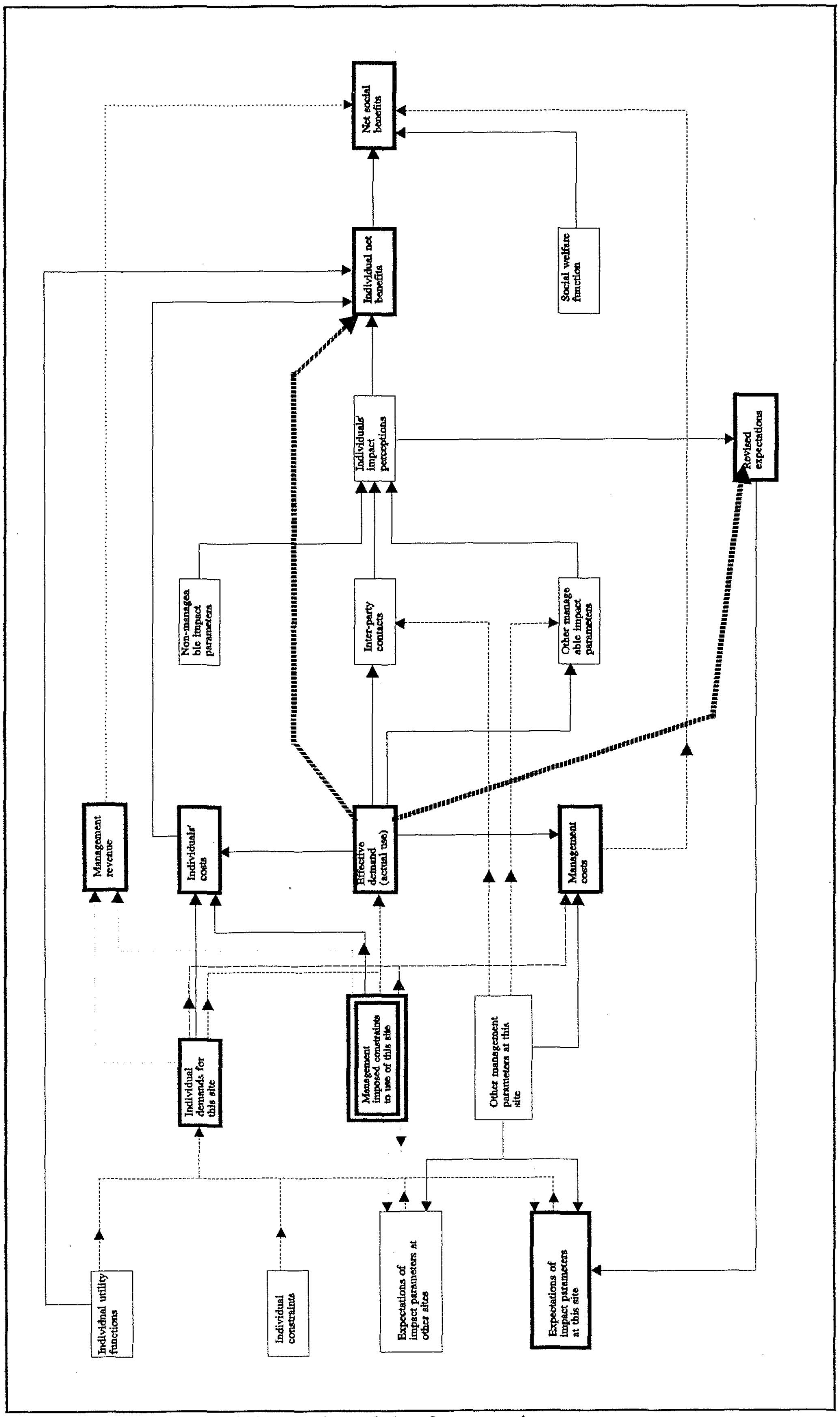


**Figure 23** Normal demand models of congestion.

use of a facility they are going to implement. Use constraints coupled with site demands determine the amount of use occurring, the amount of revenue collected, the costs incurred by management, and the costs incurred by potential and actual site users, *ceteris paribus*. Actual use and costs determine individuals' net benefits. Management revenue, management costs and individuals' benefits determine net social benefits of the facility. The equilibrium condition is captured by the link from effective demand through revised expectations to expectations of impact parameters at this site. Equilibrium can only occur when expectations are fully realised.

The simplifications introduced by the characteristics approach outlined in this chapter are illustrated in Figure 24. Rationalisation and displacement occur because of some exogenous change in demand (box with double bold borders). This change results in changes in effective demand and consequently to changes in perceptions of impact parameters. Consequently, individuals' net use benefits change, as do their expectations of impact parameters at this site. This leads to further (endogenous) changes in site demand, until equilibrium is re-established when effective and expected demand are equal. The model built in this chapter was concerned with explaining the rationalisation and displacement hypotheses and consequently did not address changes in management costs or revenue, or impacts on net social benefits.

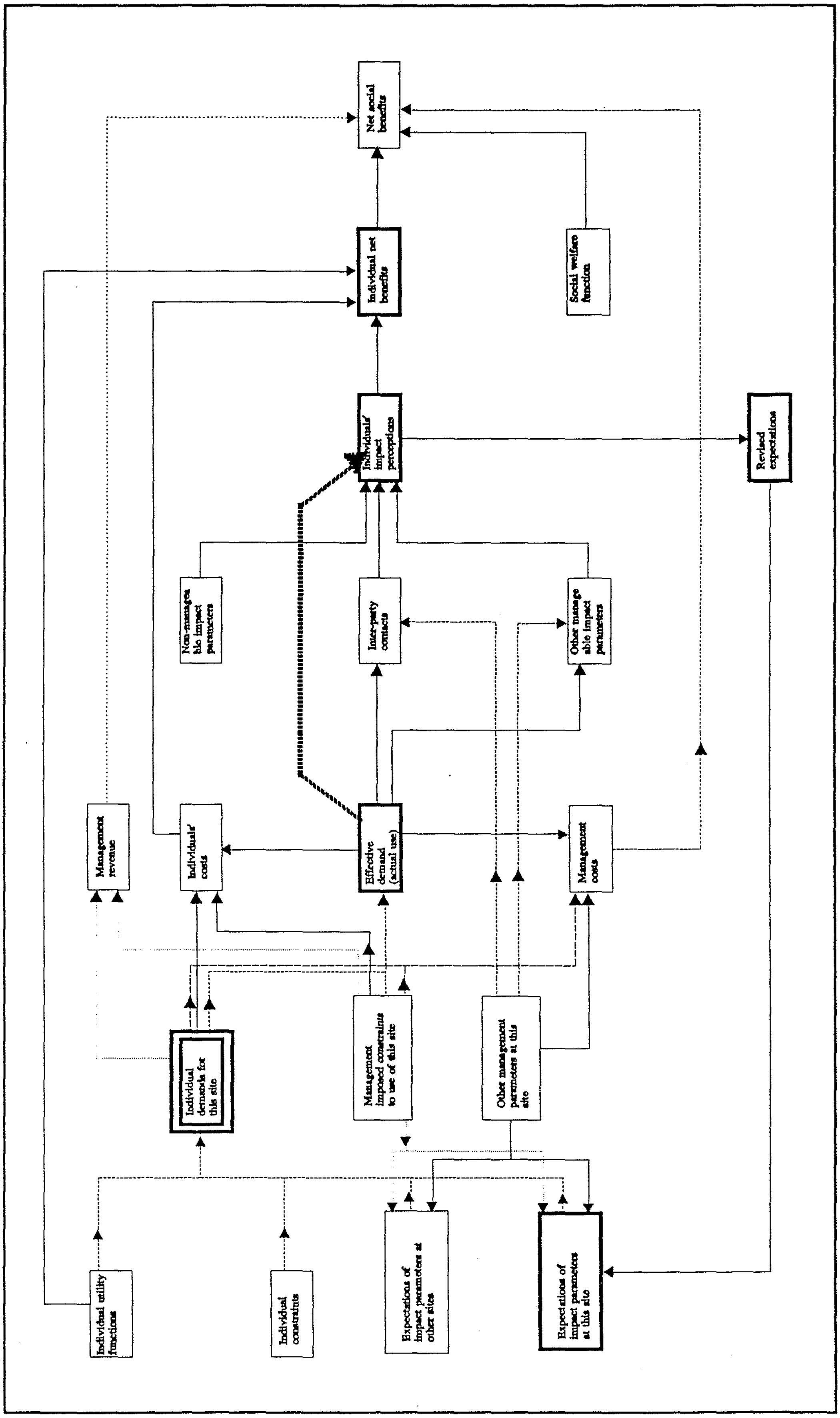


**Figure 24** Characteristics demand model.

# CHAPTER FIVE

# MANAGING CONGESTION

## 5.1 Introduction

The distribution of benefits obtained from a rationed resource is dependent upon the rationing method adopted. For example, if pricing is used, those purchasing a right to use the resource obtain benefits as consumers' surplus. The person or group selling those rights obtains monetary benefits, or rent. If other rationing methods are chosen the benefits are distributed differently. A pure lottery, for example, ensures that there is no rent. All benefits accrue to those who are successful in the lottery.

The objective of this chapter is to determine the impacts, with respect to efficiency and the benefits obtained by consumers, of adopting alternative rationing techniques to control use of a congested facility. Chapter 4 showed that the open access outcome is not optimal in efficiency terms. That is, total net benefits obtained from optimally limited use (the optimal amount of use is less than the open access level of use) of a congestible resource are greater than total net benefits if resource use is not limited. This conclusion is derived under the assumption that prices will be used to ration use.

The analysis of Chapter 4 showed that pricing can be an efficient rationing method, while lotteries are often claimed to be inherently fair (Hardin, 1969) in the sense of equality of opportunity. This chapter will compare the outcomes and optimality conditions for these two tools. Analysis is restricted to price and lottery rationing. Because price rationing is efficient (but not necessarily fair) and lotteries are fair (but not efficient) combinations of these two methods of resource allocation should allow resource managers to trade-off the two objectives. Two approaches to combining the two rationing tools will be analysed.

The chapter will progress through a discussion of the concepts of efficiency and equity to review the main rationing techniques which could be applied to outdoor recreation. This will provide a context for the following analysis and will identify the narrowness of the objectives analysed here and the alternative tools which could potentially be used to satisfy the same objectives. The wide ranges of objectives and rationing tools preclude an exhaustive examination of them here. The remainder of this chapter analyses outcomes under various lottery allocation schemes and compare those outcomes to those under a pure pricing allocation scheme.

## 5.2 Management objectives

Resource managers, amongst others, are involved in the process of determining what actions or outcomes are best. "Best" is usually interpreted to mean *most socially desirable*. Adoption of this definition implies the need to specify the society of interest (e.g. a town, a region, a country, or subsets of people for whom the resource is to be managed, e.g. backpackers or horse riders), as well as the need to define social desirability. The latter task is problematic, the resource manager having to decide how much emphasis is to be placed on competing objectives. There is little guidance on how this should be done, although the Resource Management Law Reform has recognised the problem: "Above all, the law reform has recognised the need to identify and articulate the objectives of resource management .... In their management plans, decision makers will be expected to justify their selection of management tools, and to assess the intended effect (including the environmental impacts) of what is proposed." (Ministry for the Environment, 1989: p.8).

It is commonly accepted that efficiency and equity are objectives which are of concern to resource managers. There are, of course, many others but these two consistently arise. These concepts will now be defined.

### 5.2.1 Efficiency

Any resource allocation which causes at least one person to be made better-off and no-one to be made any worse-off is *Pareto superior* to the status quo. When no Pareto superior state exists the situation is termed Pareto efficient, or Pareto optimal. The Pareto principle appears rather innocuous, but it is not devoid of value judgement since it relies upon the judgement that "social decisions be based exclusively upon individual preferences" (Russell and Wilkinson, 1979, p.400), and the judgement that everyone's preferences count (including those of the insane, criminals, and others whose preferences are currently often ignored by society).

Pareto efficiency is determined by the initial distribution of goods or utility. If the initial distribution is unacceptable the Pareto principle is unable to provide guidance regarding desirable states, and "the choice of income distribution ... is a political matter that can be solved only by value judgements through the political process" (Just *et al.*, 1982, p.11). It could be claimed that efficiency and distribution are separate matters, but "one cannot solve the problem of efficiency and distribution in two stages by first maximising the value of the social product by correctly allocating resources and then distributing the product equitably. The relative value of products depends on income distribution, which depends, in turn, on factor ownership" (Just *et al.*, 1982, p.29).

The Paretian definition of efficiency is limited in that a Pareto efficient state is not necessarily Pareto superior to states which are not Pareto efficient. Further, there is no way of judging between the many possible Pareto efficient states (or between non-efficient states). Since most actions entail negative impacts on some people, the concept of Pareto efficiency provides only a partial ordering of alternative resource allocations. The potential Pareto improvement, or compensation, criterion provides a complete ordering of resource allocations. This criterion labels proposals socially beneficial if the gainers could compensate the losers and still be made better-off by the proposed change *whether compensation is made or not.*

The Pareto and compensation criteria have different distributional implications. While the Pareto criterion implicitly recognises that individuals have a right to at least their status quo level of utility (or income, or consumption) the compensation criterion has the potential to make people both relatively and absolutely worse-off. It is therefore capable of exacerbating existing inequalities (Sen, 1973).

The compensation criterion is one version of utilitarianism, which is defined by Sen (1986, p.278) to have three elements:

(1) **Consequentialism:** The rightness of actions - and (more generally) of the choice of all control variables - must be judged entirely by the goodness of the consequent state of affairs.

(2) **Welfarism:** The goodness of states of affairs must be judged entirely by the goodness of the set of individual utilities in the respective states of affairs.

(3) **Sum-ranking:** The goodness of any set of individual utilities must be judged entirely by their sum total.

Criticisms of utilitarianism are based on ethical concerns and practical concerns. The latter are raised by the need to make interpersonal utility comparisons. However, there is no theoretically defensible way of making interpersonal comparisons of welfare (Friedman, 1985, p.38).

Utilitarianism concentrates solely on total utility and completely ignores distribution of utility. The implications of adopting a utilitarian criterion for resource allocation are unacceptable for many people. For example, under utilitarian decision rules it is acceptable to commit crimes as long as the benefits to the criminals outweigh the costs imposed upon the victims. In some cases there is partial support for such practices, as epitomised by the legend of Robin Hood. However, very few people appear willing to endorse the actions of gang rapists or murderers. The total of net individual benefits is not everything. Society is concerned about the distribution of impacts under varying states of the world.

Cost recovery for changes in provision of goods (but not for existing provision) ensures Pareto superiority, but not Pareto efficiency. Cost recovery is necessary, but not sufficient, for Pareto efficiency. The non-application of cost recovery to all activities where it is practical (examples include many health, police, and social welfare services) indicates that efficiency concerns are not always paramount in this country.

### 5.2.2 Equity

Ethical concerns arise over a variety of issues including: liberty, justice, and equality. They may be classified into two major areas, outcome equity and process equity (Friedman, 1985). The former is concerned with the equity of the distribution of goods, or welfare which actually occurs. It is not concerned with *why* the distribution has come about. On the other hand, process equity is not concerned with final distributions, but is concerned with the equity of initial distributions and the equity of processes under which distributions change.

It is not necessary to fully investigate theories of distributional morality here. A brief summary of some of the main schools of thought follows. Concepts of equity and efficiency can be defined in terms of goods, utility, income, or opportunity. The range of possibilities should be borne in mind throughout the ensuing discussion.

### 5.2.2.1 *Outcome Equity*

Outcome equity is most commonly described in terms of equality of final allocations, or in terms of the absence of envy for anyone else's allocation.

(i) Equality as a basis for equity.

The more alike are the allocations of goods (or whatever) to all individuals, the more fair is the distribution. This view of the world is often termed *egalitarianism*. A somewhat less rigid form is *specific egalitarianism*, which is "the view that certain specific scarce commodities should be distributed less unequally than the ability to pay for them" (Tobin, 1970: 448). Two main arguments support specific egalitarianism as an important goal in public policy. The first is the intuitive notion that it is inherently wrong that some people should have "less than a minimum of decency in terms of income, education, health care, or other basic needs" and the second is the observation that "an inequitable society is highly unlikely to function smoothly" (Nagel, 1984: 86).

The limiting case of egalitarianism arises when all individuals receive the same allocation. Suppose goods were distributed equally among all people. If such an initial allocation is deemed "fair" there still remains a problem regarding the evaluation of other outcomes. If such a distribution were made, the differing tastes of individuals would imply that utilities would not be equal. Some people would be better-off than others. Immediately society is faced with the issue of determining whether it is concerned for equality of goods or equality of welfare. An alternative approach is to allocate goods to equate utilities of individuals. Such a proposal requires the interpersonal comparison of utilities, which is not possible.

Differences in tastes imply that an equal distribution of goods or utility would not be stable. Individuals may make themselves better-off by engaging in trade, resulting in a non-equal distribution. There is no basis for judging the equity of outcomes subsequent to trade. Even if perfect markets exist and trade results in improvements to the welfare of some individuals without making anyone worse-off, it is unclear how the increased efficiency resulting from trade should be traded-off with the (possible) increased inequity.

Egalitarianism is criticised for two main reasons, its perversion of incentives and the belief that society prefers unequal outcomes. On the former, Milton and Rose Friedman question "what incentive is there to work and produce?" (Friedman and Friedman, 1980: 167). Since everyone obtains the same outcome, there is no incentive to work, let alone work hard or in an occupation that takes years of training. Consequently, total output is likely to be very low, reducing both total and individual welfare levels.

While Kneese (1977: 21) claims western liberal societies "usually regard ourselves as striving for an egalitarian society, the main obstacle being the possible effects on incentives of extreme redistribution measures", Tobin (1970: 448) takes the view that "Americans commonly perceive differences in wealth and income as earned and regard the differential earnings of effort, skill, foresight, and enterprise as deserved". Friedman and Friedman (1980) cite the preponderance for gambling in many societies and the unwillingness of most of the population to join communes or kibbutz as evidence that people often seek, or prefer, unequal outcomes. The divergent views of social commentators with regard to societies' acceptance of egalitarianism as a desirable outcome indicates that choice of an appropriate social welfare ordering is likely to entail some value judgement with respect to the importance of equality of the distribution of goods or utility, and any such judgement is likely to be controversial.

(ii) Envy as a basis for equity.

Another basis for determining outcome equity is *envy*, or more correctly - lack of envy. Under this view of the world an outcome is fair if no individual envies the consumption bundle possessed by any other individual (see Feldman, 1980 and especially Baumol, 1986 for discussion of this concept). The equal distribution of goods is therefore fair under this criterion. The concept is appealing in that it does not rely on inter-personal comparisons of utility. However, starting from an equal distribution (or any other envy-free distribution), trade may bring about distributions which are not considered fair (Feldman, 1980; Baumol, 1986), bringing this concept of fairness into conflict with Pareto efficiency.

This concept of equity may be criticised on the same grounds of lack of incentives and non-desirability as egalitarianism is. For example, "it is questionable whether the concept of lack of envy adequately captures the notion of fairness. One can think of cases where someone prefers the consumption bundle of someone else, yet everyone might agree that the economy is fair in the sense of being equitable. For example, I might envy a friend's 'lucky find' in an antique store yet perceive no 'unfairness' in the fact that he, not I, owns it." (Boadway and Bruce, 1984: 174-5).

(iii) A general concept of outcome equity.

Decision rules which are only able to order a sub-set of social states are termed quasi-orderings. There are several quasi-orderings which attempt to trade-off efficiency and equity. These include the dominance, hull-of-dominance, modified Rawls, egalitarian hull, and other criteria (see Blackorby and Donaldson, 1977; Russell and Wilkinson, 1979; Sen, 1986; for descriptions of some of these). The most general formulation of a social welfare function which trades-off efficiency and outcome equity is the Bergson-Samuelson social welfare function (see, for example, Russell and Wilkinson, 1979; Just *et al.*, 1982). This approach maps a utility possibilities frontier in inter-personal utility space, and determines socially optimal outcomes by overlaying a set of social indifference curves. Such a social welfare ordering may be expressed mathematically as:

$$W(x) = F(u^1(x), u^2(x),...,u^h(x))$$

where: $u^i(x)$ is the utility derived by individual i from distribution x, and

$W(x)$ is the social welfare of distribution x.

This general approach fails because of the lack of agreement on the correct specification of the social indifference curves[1] (selection of the function F), it is also unable to account for matters of process equity.

[1] That neither this approach nor any other is able to provide a ranking of states of the world based upon individual preferences, and consistent with some reasonable constraints that such a procedure would be required to satisfy, was first shown by Kenneth Arrow in the oft-cited Arrow's impossibility theorem: see K.J. Arrow Social choice and individual values. John Wiley and Sons, New York, 1951.

### 5.2.2.2 *Process Equity*

Those concerned primarily with process equity are not concerned that allocations of goods or utility, *per se*, are unequal as long as the procedures under which the goods were obtained were fair. Differences in wealth or utility may have arisen because of hard work on the part of some individuals (and lack of it on behalf of others), or because some individuals were denied opportunities to participate in the workforce, or to obtain the skills necessary to do so. In these cases equality of outcomes may be considered unfair. Sen (1986, p.282) puts it this way, "it is possible to defend a persons rights not in terms of the goodness of its *[sic]* consequences, but on the grounds that these rights have intrinsic moral acceptability irrespective of the consequences of the exercise of these rights" and proceeds to cite Nozick (1974, p.166) "Rights do not determine the position of an alternative or the relative position of two alternatives in a social ordering; they operate upon a social ordering to constrain the choice it can yield".

The principal notion of process equity is the concept of equal opportunity. For example, it may be considered unfair that some individuals are disadvantaged because of gender or race (say in ability to obtain finance or education), resulting in diminished welfare for the same amount of work as others. Policies which redistribute benefits toward the disadvantaged groups may then be considered advantageous. More contentious are concepts of equality of opportunity in terms of genetic characteristics and inheritance. Some authors claim that it is unfair that individuals can expect to obtain high utility levels simply because they are fortunate enough to be born into a wealthy family, or because they are an intellectual or sporting genius, while others are certain only of misery because of the circumstances of their births (Boadway and Bruce, 1984: 176).

The concept of process equity includes the rules for acquiring and transferring rights to goods. These rules provide the only means to obtain rights, and also provide a guarantee of obtaining a right if satisfied. Examples of such rules are provided by Locke (1690) and, more recently, by Nozick (1974). Sen (1986, p.285) notes that these rules have been widely criticised for the arbitrariness of the principles upon which they are based. The same criticism must also apply to all other notions of distributional fairness. Lottery allocation of scarce resources is one means of attaining equality of opportunity. All individuals retain a right to enter the lottery, but only successful entrants obtain rights to use the resource. If the lottery is run on an equal-chance basis (i.e. no individual has a greater probability of success than others) then the lottery can be viewed as a non-discriminatory, or equal opportunity, method for allocating a resource.

### 5.2.3 Conclusion

Given that "in popular discourses fairness is an amalgam of a multiplicity of ad hoc desiderata that no simple and analytically tractable formulation may be able to capture" (Baumol, 1986, p.11), and "no unique concept of equity is widely regarded as definitive for public policy making" (Friedman, 1984, p.40) it is not possible for the analyst to determine "the socially best" action or policy. Indeed, it appears that society may not apply the same criteria to all things. For example, many societies appear to emphasise strict egalitarianism in allocating one vote per adult and taking considerable effort to prevent trade in votes, while specific egalitarianism is emphasised by the same societies in providing a minimum standard of health care for all, equality of opportunity is emphasised in the concept of free and compulsory education, whereas liberty and the Pareto improvement criterion appear to guide allocation of most goods and services judged to be non-essentials. Somewhere in the decision making process some person, or group, must make a value judgement regarding social morality with respect to target variables and their distribution.

Friedman (1984, p.47) reaches the following conclusion regarding the role of economic analysis in the policy process:

> "The diversity of specific concepts of efficiency and equity should receive attention. Given the lack of any predetermined social consensus about which of them to apply and how to integrate those that do apply, policy analysis can usually best help users reach informed normative conclusions by clearly laying out its predictions and evaluating them by the different normative elements (e.g., efficiency, relative efficiency, equality, equal opportunity). Certainly, nontechnical users will find each of the elements more familiar or at least easier to understand than the concept of a social welfare function."

Atkinson (1970) and Sen (1973) discuss a wide range of measures of equality. Atkinson concludes that:

> "a complete ranking of distributions cannot be reached without fully specifying the form of the social welfare function ... examination of the social welfare functions implicit in these measures shows that in a number of cases they have properties which are unlikely to be acceptable, and in general there are no grounds for believing that they would accord with social values" (Atkinson, 1970, p.262).

Summary measures of efficiency and equity are not free of value judgements, leading to the conclusion that, in the absence of detailed information on the social desirability of relevant states, the best that the analyst can do is to provide a description of the impacts experienced by individuals and groups, and/or supply summary measures while taking care to indicate the value judgements implicit in their adoption.

In this context, this study investigates the implications of choice ofone of two resource allocation procedures. As stated previously, the procedures chosen are price rationing, because it is efficient, and lottery rationing, because it is fair. The specific definition of efficiency adopted is the sum of willingness to pay for all individuals, while that for fairness is equality of opportunity. This study investigate the efficiency costs of lottery rationing of congestible resources.

## 5.3 Resource allocation tools

A variety of resource allocation tools is available. At the limits are the options of doing nothing (i.e. open access, or allocation by crowd-tolerance) and completely precluding access to resources. It is assumed here that the management agency wishes to allow some use of a congestible resource, but less than would occur under open access. Hence, while admitting that the polar cases are applicable management options they will not be investigated further here.

Shubik (1970) identifies eight major means of resource allocation:

(1) economic markets with prices

(2) voting

(3) bidding

(4) bargaining

(5) higher authority, fiat, or dictatorship

(6) force, fraud, deceit

(7) custom, including gifts and inheritance

(8) chance.

Publicly-owned outdoor recreation resources are commonly only allocated by a sub-set of these alternatives (1,3,4,5,8; Hendee, Stankey and Lucas, 1990). Allocation methods are divided into two major categories; market and non-market allocation tools. Market tools are characterised by agreement between trading partners with regard to the amount of one good to be exchanged for another.

## 5.3.1 Market allocation tools.

### 5.3.1.1 *Uniform prices*

Scarce goods may be allocated by setting a single, market clearing price, allowing everyone to consume as much as they desire at that price. Chapter 4 identified how to find prices which maximise consumer, producer, and aggregate benefits from a congestible resource.

If the market demand curve is known with certainty, the market clearing price ($P_0$) may be chosen and the desired quantity ($Q_0$) sold. However, demand is uncertain, at best, and for environmental commodities is often completely unknown. By choosing a price not equal to $P_0$ demand will vary from the target level of use, $Q_0$.

If a price greater than $P_0$ is chosen demand will be less than $Q_0$ and *vice versa*. The effects of divergences from $P_0$ depend upon where $P_0$ is in relation to the prices which maximise consumer and producer benefits and the magnitude of the divergence. Consumers and the producer could become better or worse-off by a price change in either direction, depending upon the particular circumstances.

When value is measured by willingness to pay, the market clearing price is known with certainty, and markets operate perfectly, uniform pricing is an efficient means of allocating a fixed quantity of a resource, since all those willing to pay at least the market clearing price obtain access to use, while those willing to pay less than this price fail to obtain access. In other words, no-one who fails to obtain access to the good has a greater willingness to pay than anyone who does obtain access. When benefits are measured by willingness to pay, pricing has the advantage of providing a measure of the value of additional capacity.

Pricing may not be a feasible means of allocating some natural resources because of the inability to exclude non-payers from using the resource. Access to national parks and state forests are likely cases. Of course, this criticism applies equally to other methods, such as lotteries and reservations, but not to all (e.g. effort). A notable exception in New Zealand parks is provided by commercially operated guided tramping where capacity is limited by the terms of the concession. The ready identification of those who have paid allows these operations to charge prices which limit demand to capacity.

The main distributional justice concerns are that pricing discriminates not only on grounds of willingness to pay, but also on grounds of ability to pay. Concern about discrimination on willingness to pay grounds is an expression that consumers' surplus does not provide a relevant measure of benefits, while concern about discrimination on ability to pay grounds is founded on the belief that the existing pattern of wealth distribution is inappropriate.

#### 5.3.1.2 *Discriminatory pricing*

Discriminatory pricing is a term used to describe a variety of techniques which producers with some market power are able to apply to appropriate some of the consumers' surplus that uniform pricing does not give them access to. This is done by charging different prices for different people purchasing identical goods, the price charged being dependent upon the individual's demand characteristics. Typical examples include: student and senior citizen discounts, season tickets, tied purchases, peak-load pricing, connection fees, quantity discounts, and minimum hire requirements.

Price discrimination is inefficient unless it can be carried out perfectly and costlessly. Perfect price discrimination does not occur in practice (Phlips, 1983), although second and third degree price discrimination are common. Pre-requisites for application of discriminatory pricing are market power, the ability to distinguish members of the various types of user groups, knowledge of their demand characteristics, and the ability to preclude trade in the commodity between groups.

#### 5.3.1.3 *Vouchers*

Prices may be set in terms of money, or some other form of currency, which may or may not be exchangeable for money. Such other currencies are usually termed ration coupons, permits, or vouchers, and have commonly been used to ration foodstuffs and other basic requirements during wartime. Vouchers may be directly redeemable for goods, or may also require money transactions. Demand for rationed commodities is restricted by the number of vouchers allocated. Distributional and efficiency impacts of vouchers are determined by their method of initial distribution and whether trade in vouchers is permitted. A white market occurs when trade in vouchers is permitted, while restrictions on trade often result in illegal trading (black markets) as individuals attempt to appropriate the gains to be made from transferring vouchers from low to high value recipients.

#### 5.3.1.4 *Auctions*

Auctions require the exchange of money for rationed goods, but the exchange price is not predetermined. Price is determined at the time of sale by bidding. Bids are offers to buy at stated prices. Cassady (1967) describes the main types of auction mechanisms used worldwide. These include the English, Dutch, and simultaneous auctions. Many other forms of auction exist, but they are essentially variations on one or more of the three main types. The different forms of auction have different implications for revenue generation and efficiency of resource allocation (Kerr, 1990). In general, auctions which allocate a single item are efficient, but those that allocate many identical or similar items are inefficient.

Auctions are useful when there is uncertainty regarding demand for the goods being allocated, or when a quick sale must be made. If the seller knew buyer demand functions it would be possible to use discriminatory pricing schemes to obtain a better return than could be obtained from disposing of the same goods by auction.

### 5.3.2 Non-market allocation tools.

#### 5.3.2.1 *Lottery*

The lottery is a method of allocation by chance. In simple lotteries all participants have an equal probability of success, however it is possible to apportion successes amongst different categories of participants to alter the probability of success for the different categories. In its simplest form, all those wishing to consume the rationed good have their names recorded and at some predetermined time names are drawn randomly to determine successful applicants.

Pure lotteries are open to all and are free of any qualifying conditions or fees. Impure lotteries may require that applicants meet some merit requirement, queue for the limited number of ballots, or pay fees for entering or success in the lottery.

Lotteries are impartial and therefore are often viewed as being "eminently fair" (Hardin, 1969). They are relatively simple for consumers to partake in once consumers are aware of their existence and structure), but impose high transaction costs on managers (for eaxample, to ensure all applicants are included in the draw, duplicate applications are not included, and all applicants are advised of the outcome). The uncertainty of outcomes may induce individuals to enter many lotteries simultaneously, when they are only able to benefit from one "win". This and the long lead times required to administer a lottery result in a large proportion of "no-shows" - people who are successful in a lottery but who do not exercise their rights to consume the rationed good.

The no-show problem may be dealt with by increasing the number of successes in the lottery to obtain the same expected number of users, or by allocating no-shows on the day by some other method, such as queuing or pricing. The former approach is suitable for allocating services or goods where the quantity constraint is not strictly binding in the short-term. An example is provided by outdoor recreation areas where use is limited because of the ecological impacts of the total amount of use, and where the amount of use in any one day (for example) may not be critical. This approach clearly does not work for other goods where the quantity constraint is strongly binding, such as access to a hunting block where safety and non-disturbance of game are prime concerns.

Because "a lottery would not discriminate among users according to the relative value they place on the [resource,] persons who entered the lottery frivolously or to whom [the resource] is relatively unimportant would hold the same chance of winning as the ... enthusiast" (Stankey and Baden, 1977:7), lotteries are inefficient however value is defined.

### 5.3.2.2 *Reservation*

Reservation is a commonly used tool (in association with pricing) for allocating accommodation and travel and (without pricing) hunting blocks. The first person to request consumption of a given unit of the good is allocated that unit. By reserving far enough into the future one may (almost) be guaranteed to obtain the rationed good.

Several authors (e.g. Shelby and Danley, 1979; Stankey and Baden, 1977) have questioned the fairness of this system which favours those with long planning horizons. This is the main reason that in many cases where the reservation method is used not all units of the rationed good are allocated by this method. To better meet the needs of those who are unable to plan long-term some units may be allocated by pricing or queuing at time of use. An example is air travel. By reserving early it is possible to obtain low priced seats, while some seats are retained to satisfy the demands of urgent, short-notice travellers who are required to pay more for them.

### 5.3.2.3 *Queues*

Queues are similar to pricing in that they impose a time price for use of a resource. Reservations are an application of the first-come first-served principle prior to the time of use, and often remote from the physical location of the good. Reservations can result in instant confirmation of future use for the user. Queuing, on the other hand, is first-come first-served at time of use, usually at the physical location of the good. Queues therefore eliminate the problem of no-shows at the cost to consumers of increased uncertainty. Queues may be either physical (e.g. waiting in line) or paper (e.g. waiting lists for state housing). In either case, the person who has been waiting the longest obtains the next unit of the good to be distributed.

It is often argued that because everyone is equally endowed with time queuing is the fairest means of resource allocation. Fairness only comes at the cost of efficiency however, as time spent queuing (and travel costs for physical queues) is wasted, those who obtain access to the resource do so by paying with their time, however those who do not obtain access also pay. Further, the marginal value of time is not the same for all individuals. Those who place a low value on their time (probably the unemployed, old people, and those in low earning occupations) will clearly be advantaged by physical queues relative to those who place a high value on their time (business executives, people on short holidays, etc), while paper queues will disadvantage those for whom time of use is important.

Paper queues impose costs upon the management agency to deal with applications to join the queue, updating positions on the queue, and informing queuers of their position. Because a paper queue is essentially costless to the consumer, and there is uncertainty over the time of success, the paper queue will be subject to the same no-show problems as lotteries and reservations.

Physical queues impose management agency costs to prevent queue jumping, to provide facilities for the queuers, and to administer the rationing mechanism, which will require the physical presence of an agency representative in many instances.

#### 5.3.2.4 *Merit*

Goods may be allocated only to people satisfying arbitrary qualifications. These qualifications may be related to past behaviour or skills in use of the good. For example, in introducing individual transferable quotas to New Zealand fisheries the initial distribution of quotas was determined by historical involvement in the fishery. Alternatively, allocations may be made on any arbitrary basis, such as racial or socioeconomic background as a proxy for need or deservedness, or friendship with the decision making authority.

#### 5.3.2.5 *Effort*

A special class of merit rationing is rationing by effort. It is common to find natural resources rationed by effort. In this country, wilderness area management guidelines indicate that these areas should require (even though they don't always) one day's walk to reach their boundaries. This , along with the difficulty of access to many publicly provided outdoor recreation areas has led Cullen (1985:7) to describe effort as "the New Zealand way of rationing", in respect to outdoor recreation. Effort need not be applied directly to the target activity. It could be regarded as a price which may be levied in any unit. For example, wapiti hunting blocks in Fiordland have been partly rationed by the requirement that applicants must have contributed to animal management operations in the area.

Because effort required to obtain access to a resource is often 'wasted' rationing by effort is inefficient. Effort rationing discriminates amongst those with different abilities to supply effort, e.g. the old or physically, mentally, or financially less able members of society. If this method is applied as a once only requirement, it will work like a two-part tariff with a zero marginal price. This will effectively discriminate against casual or infrequent resource users.

In many instances, increases in demand will cause problems as effort requirements to meet any desired level of use will have to be amended upwards. This may be quite infeasible in rationing some resources. Public roads and rail services, for example, cannot be closed or rerouted simply to control access to a wilderness area. It may be equally as absurd to increase proficiency requirements to levels requiring extraordinary levels of knowledge, or extraordinary investment to obtain that knowledge. If, however, little investment is required to meet requirements, then effort is unlikely to provide a useful management tool. High effort requirements are therefore likely to be both discriminatory and inefficient. Low effort requirements are likely to be ineffective.

### 5.3.3 Conclusion

There is a wide variety of methods available for allocating congestible resources. Each method has different efficiency and distributional implications. This study has chosen to further analyse the relative impacts of simple pricing and lottery allocation mechanisms to increase understanding of the efficiency costs of furthering the objective of process equity. The pricing allocation method has been chosen because it is (theoretically) efficient and has long been championed by economists. It is not used in publicly provided wilderness recreation in New Zealand, or in the United States (Hendee, Stankey and Lucas, 1990). Pricing is commonly used to allocate privately provided wilderness recreation here and overseas. Lottery allocation is widely used in the United States and occasionally in New Zealand. It has been touted as the most fair allocation method.

The focus on lottery and pricing allocation methods does not infer that similar consequences could not be achieved using other allocational methods. More complete analyses of the implications of adoption of specific allocation methods in wilderness recreation are provided by Hendee, Stankey and Lucas (1990), Shelby and Danley (1979) and Stankey and Baden (1977).

## 5.4 Comparison of price and lottery allocation methods

Chapter 4 analysed efficiency conditions for price-rationing of congestible resources and provided measures of benefits under price-rationing. This section measures benefits obtained from a congestible resource under lottery-rationing and compares the efficiency of the two allocation schemes. For simplicity, unless stated otherwise, the following assumptions will hold throughout the analysis:

(i) Transaction costs are zero for producers and consumers.

(ii) A fixed amount of a single type of use is permitted. That quantity of use is determined by the management authority with regard to whatever objectives it chooses to pursue.

(iii) Marginal social cost of resource use is zero for all use levels.

### 5.4.1 Lottery

A pure lottery does not charge a fee for entering the lottery, or from the successful participants. Impure lotteries may charge for one or both of participation and success. These lotteries are a mixture of pricing and a pure lottery. Initial analysis will be limited to pure lotteries only, but will be extended at a later stage.

Since no fees are charged under a pure lottery, there is no rent earned from the resource. All benefits accrue to consumers in the form of consumers' surplus. Unlike pricing, it is not possible to determine *a priori* which potential consumers will obtain access to the resource under lottery rationing. If different consumers obtain different benefits from use, total benefits of use under a lottery are uncertain. However, as long as the relevant constant crowding demand curve is known, so is the probability of any individual being successful in the lottery, and therefore the distribution of total benefits is also known. By the law of large numbers, expected benefits are an appropriate measure of the benefits obtained from resource use when the number of potential users is very large for each allocation exercise, or when there are many allocation exercises.

Suppose the resource manager chooses to employ a pure lottery in which there will be X successful participants. At zero price, and a constant level of crowding of X, there will be Q = F(0,X) units of use demanded (from Equation 4.2). Expected consumers' surplus is therefore equal to mean consumers' surplus with expected use level X, multiplied by the number of users (X), see Equation 5.1.

$$E[B] = E[CS] = \frac{X}{Q}\int_{0}^{Q=F(0,X)} \phi(X^{d},X)dX^{d} = \frac{XA}{Q} \qquad 5.1$$

where X is the target level of resource use,

$X^d$ is the amount of resource use that people expect to experience,

$\phi$ is the inverse constant-crowding demand function, and

Q is the amount of resource use that would occur if there were no rationing and expected use was X.

The most efficient capacity for a lottery rationed resource is found by choosing X to satisfy Equation 5.2.

$$\frac{\partial B}{\partial X} = 0$$

$$= \frac{A}{Q} + \frac{X}{Q}\frac{\partial A}{\partial X} - \frac{XA}{Q^2}\frac{\partial Q}{\partial X} \qquad 5.2$$

where

$$\frac{\partial A}{\partial X} = \int_0^{Q=F(0,X)} \phi_2(X^d,X)dX^d$$

## 5.4.2 The linear case

As an example of the divergence in impacts between pricing and lottery allocation consider the case of a linear constant crowding demand function. Let $\phi = a+bX^d+cX$ be the Marshallian constant crowding demand function, with $b<0$ and $c<0$. The market demand function is therefore $\Theta = a+(b+c)X$. For simplicity, assume that supply costs are zero and that Marshallian surplus provides a close approximation to Hicksian surplus.

### 5.4.2.1 *Lottery rationing*

With lottery rationing, expected consumers' surplus is equal to expected total benefits, and rent is zero. For any arbitrary capacity (X) less than the open-access capacity:

$$E[CS] = E[B] = X(a+cX)/2 \qquad 5.3$$

and the per capita consumer surpluses are:

$$E[CS_a] = -X(b+c)(a+cX)/2a \qquad 5.4$$

$$E[CS_b] = (a+cX)/2 \qquad 5.5$$

$$E[CS_c] = -bX/2 \qquad 5.6$$

From 5.3, expected consumers' surplus is maximised when:

$$X = -a/2c \quad (\text{if } b>c)$$
$$= -a/(b+c) \quad (\text{if } b\leq c) \qquad 5.7$$

The reason for the second part of Equation 5.7 is: maximum expected consumer surplus from a lottery occurs at $X=-a/(2c)$. However, the case where $b<c$ leads to the condition $[-a/(2c)] > [-a/(b+c)]$, where the second term of the inequality is the open access level of use. The impossibility of using a lottery to obtain a use level greater than that occurring with open access justifies the second condition. Since a lottery is only able to increase consumer surplus when $b>c$, maximum expected consumers' surplus is:

$$(E[CS])_{maximum} = -a^2/8c \qquad 5.8$$

### 5.4.2.2 *Price rationing*

Benefit measures are found by substituting the demand function into Equations 4.5 to 4.10:

$$R = aX + (b+c)X^2 \qquad 5.9$$
$$B = aX + (bX^2)/2 + cX^2 \qquad 5.10$$
$$CS = B\text{-}R = -(bX^2)/2 \qquad 5.11$$
$$CS_a = bX^2(b+c)/2a \qquad 5.12$$
$$CS_b = -bX/2 \qquad 5.13$$
$$CS_c = X^2(a+cX)/2 \qquad 5.14$$

Section 4.4 provides the following conditions for a linear demand specification:

Total benefits are maximised when:

$X = -a/(b+2c)$ i.e. $P = ac/(b+2c)$ 5.15

Producer's surplus is maximised when:

$X = -a/[2(b+c)]$ i.e. $P = a/2$ 5.16

Consumers' surplus is maximised when:

$X = -a/(b+c)$ i.e. $P = 0$ 5.17

## 5.4.3 Comparison of the outcomes of price and lottery rationing for the linear case

The results of Section 5.4.2 allow comparison of benefits under lottery and pricing allocation schemes for the linear demand curve case.

### 5.4.3.1 *Revenue*

Clearly, since a pure lottery is unable to generate revenue, price allocation is superior at generating revenue.

### 5.4.3.2 *Total benefits*

The difference between total benefits under the two allocation schemes for some arbitrary capacity (X) is:

$E[B_L] - B_P = -(X/2)(a+[b+c]X)$ 5.18

which is less than zero for all X less than the open access level of use. For <u>any</u> capacity, price allocation is more efficient than lottery allocation.

### 5.4.3.3 *Aggregate consumer benefits*

The difference between aggregate consumer surplus under the two allocation schemes for some arbitrary capacity X is:

$$E[CS_L] - CS_P = (X/2)(a+[b+c]X) \qquad 5.19$$

which is greater than zero for all X less than the open access level of use. For any capacity, price allocation provides fewer consumer benefits than lottery allocation.

### 5.4.3.4 *Per-capita consumer benefits with identical, arbitrary capacities*

For any arbitrary capacity (X) the difference between per-capita benefits expected under lottery rationing and those obtained under price rationing are:

$CS_a$: $CS_a = CS/X_{oa}$ where $X_{oa}$ = the open-access use level

Therefore,

$$E[CS_{a,L}] - CS_{a,P} = (E[CS_L] - CS_P)/X_{oa} \qquad 5.20$$

which, from Equation 5.19, is positive. On average, those using the resource prior to rationing would expect to obtain greater benefits under lottery rationing than under price rationing.

$CS_b$: $CS_b = CS/X$ where X is the rationed use level

Therefore,

$$E[CS_{b,L}] - CS_{b,P} = [a+(b+c)X]/2 \qquad 5.21$$

which is greater than zero whenever X is less than the open-access level of use. On average, those obtaining use of the resource would be better-off under lottery rationing than under price rationing.

**$CS_c$:** $CS_c = CS/X_R$ where $X_R$ is the amount of use demanded at zero price with crowding equal to X

$$E[CS_{c,L}] - CS_{c,P} = (E[CS_L] - CS_P)/X_R \qquad 5.22$$

which is positive.

### 5.4.3.5 *Per-capita consumer benefits with efficient pricing and the most efficient lottery*

It follows directly from Equation 5.19 that expected $CS_a$ for the most efficient efficient lottery ($E[CS_{a,L}^*]$) is greater than $CS_a$ with efficient pricing ($CS_{a,P}^*$).

Comparison of Equations 5.7 and 5.15 indicates that the most efficient capacity for a lottery ($X_L^*$) is greater than the most efficient capacity for pricing ($X_P^*$), so the relative magnitudes of $CS_b^*$ are not immediately apparent. Comparing the definitions for these terms leads to the conclusion that:

$$E[CS_{b,L}^*] - CS_{b,P}^* = [a(b+3c)]/[8(b+2c)] \qquad 5.23$$

which is unambiguously greater than zero.

Because $X_L^*$ is greater than $X_P^*$ the number of people wishing to obtain access to the resource for the efficient capacity under a lottery is less than the number of people wishing to obtain access to the resource at zero price when capacity is at the efficient price-rationed level. Therefore, $E[CS_{c,L}^*]$ is greater than $CS_{c,P}^*$.

### 5.4.4 *Comparison of lottery-rationed outcomes with open-access outcomes for the linear case*

Under both lottery and open-access allocation schemes all benefits occur in the form of consumer surplus. Neither scheme results in any revenue collection. The expected efficiency gains from implementation of an efficient lottery are:

$$\Delta B = E[CS_L^*] - CS_{OA}$$

$$= (-a^2/8c) - (-ba^2/2(b+c)^2)$$

$$= [a^2(c-b)(b-c)]/[8c(b+c)^2] \qquad 5.24$$

$$\Delta B = 0 \text{ when } b=c$$

$$\Delta B > 0 \text{ when } b \neq c$$

Equation 5.24 indicates that, when demand curves are linear, it is possible to improve aggregate (expected) consumer welfare by appropriate use of lottery rationing. Further, since the open-access solution yields at least as much consumer surplus as any price-rationed solution, it is always possible to obtain more (expected) consumer welfare through appropriate use of lottery rationing than is possible with price rationing.

By definition, an efficient lottery must increase aggregate consumer surplus above that obtainable with open-access, regardless of demand specifications (see Equation 5.24 for confirmation of this for the linear case). Therefore, $CS_a$ must increase upon implementation of efficient lottery rationing ($CS_{a,L}^* > CS_{a,OA}$). No conclusion can be reached regarding the change in $CS_b$ or $CS_c$ under lottery rationing without specific demand information. For the linear case the outcomes are:

From the definitions, the following two conditions must hold:

(i) $E[CS_{b,L}^{*}] > E[CS_{a,L}^{*}]$

(ii) $E[CS_{a,L}^{*}] > CS_{a,OA} = CS_{b,OA}$

Which imply that:

$E[CS_{b,L}^{*}] > CS_{b,OA}$

$$E[CS_{c,L}^{*}] - CS_{c,OA} = [ab(b-c)]/[4c(b+c)] \qquad 5.25$$

which has a sign opposite to that of b-c. Since a lottery would only be used when b>c, the sign of Equation 5.25 must be negative.

### 5.4.5 *Comparison of price-rationed outcomes with open-access outcomes for the linear case*

The price increase necessary to decrease use and shift the constant crowding demand curve causes a transfer of benefits from consumers to the producer. With linear demand schedules, aggregate consumer surplus with price rationing is maximised at zero price. Since aggregate consumer surplus declines with the introduction of price rationing then $CS_a$ must be less than its open-access level whenever price rationing is used.

$CS_{a,P} < CS_{a,OA}$

Similarly, since a decline in capacity makes use more attractive, the number of people wishing to make use of the resource if access were free at this capacity increases. Consequently $CS_c$ is lower under price rationing than under open-access.

$CS_{c,P} < CS_{c,OA}$

Equation 5.26 indicates that $CS_b$ is reduced from its open-access level by efficient price rationing.

$$CS_{b,P}^{*} - CS_{b,OA} = \{ba(b+c)/[2(2c+b)^2]\} - \{ba/[2(b+c)]\} \qquad 5.26$$

which, upon rearranging, is:

$$CS_{b,P}^{*} - CS_{b,OA} = - [bac(3c+2b)]/[2(b+c)(2c+b)^2]$$

which is less than zero.

### 5.4.6 Summary and conclusions

Sections 5.4.2 to 5.4.5 have summarised the impacts of price, lottery and open-access allocation methods for a congestible resource, where the demand for that resource is linear. Analysis of a specific functional form does not provide results which are applicable to other functional forms. The analysis of the linear function has been included here to indicate how different benefit measures may be used to identify some of the equity implications of alternative allocation procedures. However, during the analysis of the relative magnitudes of impacts some results were able to be derived without making use of any specific demand data, they are generalisable to any functional form. The generalisable results are highlighted in Table 3.

The analysis includes only a small number of benefit measures (6) and only three allocation procedures (price, lottery and open-access), but produced a large number of benefit comparisons. Clearly, the comparison of all outcomes from all allocation methods would be a monumental task. The findings of the analysis of relative benefit measures for linear demand functions follows.

The ranking of capacities at which various objectives are maximised (for linear demand specifications) is:

$k_R < k_B < k_L \leq k_{OA} = k_{CS}$

| | | |
|---|---|---|
| $k_R$ | = | price rationed capacity which maximises rent |
| $k_B$ | = | price rationed capacity which maximises total benefits |
| $k_L$ | = | lottery rationed capacity which maximises expected total benefits (and total consumers' surplus) |
| $k_{OA}$ | = | open access use level |
| $k_{CS}$ | = | price rationed capacity which maximises consumers' surplus. |

Table 3 summarises the relative magnitudes of benefit measures for the linear demand function case. If resource users are risk neutral, they will prefer a lottery to pricing because, while pricing may be efficient, the gains from efficiency will not flow to the resource users unless they are also the resource owners. Resource users with linear demand schedules will expect to lose from efficient pricing of the resource, and so can be expected to protest against the implementation of such policies.

**TABLE 3** Relative benefit magnitudes for linear demand functions.

| Category of benefits | Efficient Lottery vs Open access | Efficient Price vs Open access | Efficient Price vs Efficient Lottery | Price vs Lottery (Arbitrary, equal capacity) | Rankings |
|---|---|---|---|---|---|
| Revenue | $L^*=OA=0$ # | $P^*>OA$ # | $P^*>L^*$ # | $P>L$ # | $P>L=OA$ |
| Total Benefits | $L^*>OA$ # | $P^*>OA$ # | $P^*>L^*$ # | $P>L$ # | $P>L>OA$ |
| Aggregate Consumer Surplus | $L^*>OA$ # | $P^*<OA$ @ | $P^*<L^*$ @ | $P<L$ | $L^*>OA>P^*$ |
| $CS_a$ | $L^*>OA$ # | $P^*<OA$ @ | $P^*<L^*$ @ | $P<L$ | $L^*>OA>P^*$ |
| $CS_b$ | $L^*>OA$ # | $P^*<OA$ | $P^*<L^*$ | $P<L$ | $L^*>OA>P^*$ |
| $CS_c$ | $L^*>OA$ | $P^*<OA$ @ | $P^*<L^*$ | $P<L$ | $OA>L^*>P^*$ |

Note: $L>OA$ should be read to mean "The magnitude of benefits under lottery allocation is greater than the magnitude of benefits under open-access, for the relevant category of benefits."

* The asterisk signifies an efficient application of the relevant allocation method.

\# These relative magnitudes are true for all negative sloping demand functions, irrespective of functional form.

@ These relative magnitudes are true for all cases in which maximum consumer surplus under price allocation is attained with price equal to zero.

## 5.5 Mixed price and lottery allocation methods

Pure price allocation is efficient, while pure lottery allocation ensures equality of opportunity. Resource managers may not wish to pursue either of these objectives exclusively, or may be required to provide equal opportunity while earning revenue. A combination of the two approaches provides one way of reaching intermediate allocations. Two major classes of mixed price and lottery allocation methods exist, they are lotteries which charge a fee of successful applicants prior to allowing them access to a resource, and lotteries for which a fee must be paid to enter the lottery. The following sections analyse the outcomes under these two approaches.

### 5.5.1 Lottery with a fee for successful applicants

Suppose that $X_0$ units of a resource are to be allocated by a lottery. Further, suppose that a fee $P_3$ is charged for successful lottery entrants and all entrants are aware of the fee prior to entering the lottery. Only those potential users who would obtain per-unit benefits greater than or equal to $P_3$ would enter the lottery. This situation is illustrated in Figure 25. Mean benefits for those entering the lottery are raised from $P_L$ when there is a pure lottery to $P_S$ when there is a success fee. The result of eliminating those obtaining the smallest use benefits in this way is an improvement in efficiency *vis a vis* the pure lottery. In the limit as the success fee is raised to the competitive price total benefits become identical to those obtained from a fixed, competitive price ($P_0$) as only those willing to pay $P_0$ enter the lottery and the probability of success is unity.

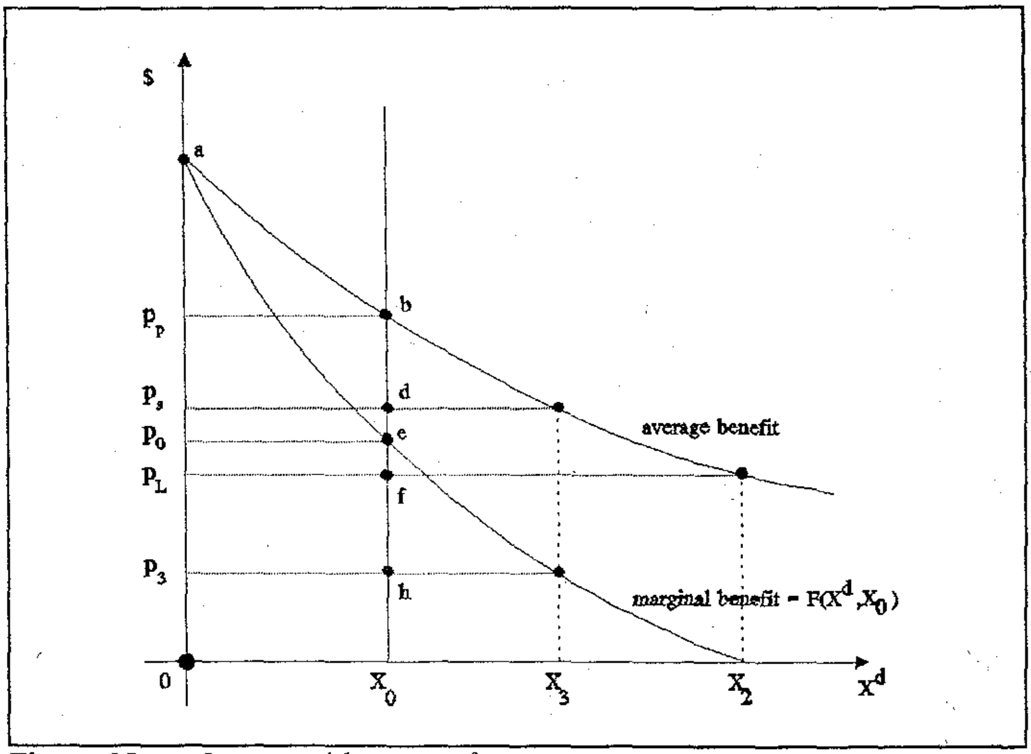


**Figure 25** Lottery with success fee

At success-fee $P_3$ the number of people entering the lottery will be $X_3=H(P_3,X_0)$, where H(.) is the constant crowding demand function associated with $X=X_0$. Benefit levels are then:

$$R = X_0P_3 \quad 5.27$$

$$= \text{area } 0P_3hX_0$$

$$E[CS] = \{(X_0/X_3).\int_0^{X_3} F(X^d,X)\, dX^d\} - X_0P_3 \quad 5.28$$

$$= \text{area } P_3P_Sdh$$

$$E[B] = (X_0/X_3).\int_0^{X_3} F(X^d,X)\, dX^d \quad 5.29$$

$$= \text{area } 0P_SdX_0$$

### 5.5.2 Lottery with a fee to enter the lottery

Analysis of outcomes resulting from a lottery in which there is a non-refundable participation fee ($p_4$) is complicated by the fact that the expected benefits of paying the fee are determined by the number of people entering the lottery. If individuals do not have accurate information on the likely actions of others, choosing an optimal policy becomes problematical. For the sake of analysis, assume that individuals know each others' preferences intimately, or there has been a long history of similar lotteries to provide an accurate estimate of the probability of success ($\pi$).

Success in a lottery results in benefits to the individual equal to $\alpha$-$p_4$, where $\alpha$ is the individual's willingness to pay for access to one unit of the good. Failure to win the lottery results in a loss of $p_4$. The expected benefit to the individual of entering the lottery is therefore:

$$E[CS] = \pi(\alpha - p_4) - (1-\pi)p_4$$
$$= \pi\alpha - p_4$$

The expected benefits of not entering the lottery are zero. Risk neutral individuals will enter the lottery as long as the expected benefits of doing so are at least as great as from abstaining. That is, a risk neutral individual will enter the lottery as long as $\pi\alpha \geq p_4$. Alternatively, only those individuals with marginal benefits ($\alpha$) at least as great as $\beta$ ($\beta = p_4/\pi$) will enter the lottery, resulting in $X_4 = H(\beta, X_0)$ applicants (Figure 26). Note that the probability of success is determined by the number of applicants ($\pi = X_0/X_4$), providing three equations in three unknowns; $X_4$, $\beta$, $\pi$. The three equations are:

(i) $\beta = p_4/\pi$

(ii) $\beta = F(X_4, X_0)$ [or, $X_4 = H(\beta, X_0)$]

(iii) $\pi = X_0/X_4$

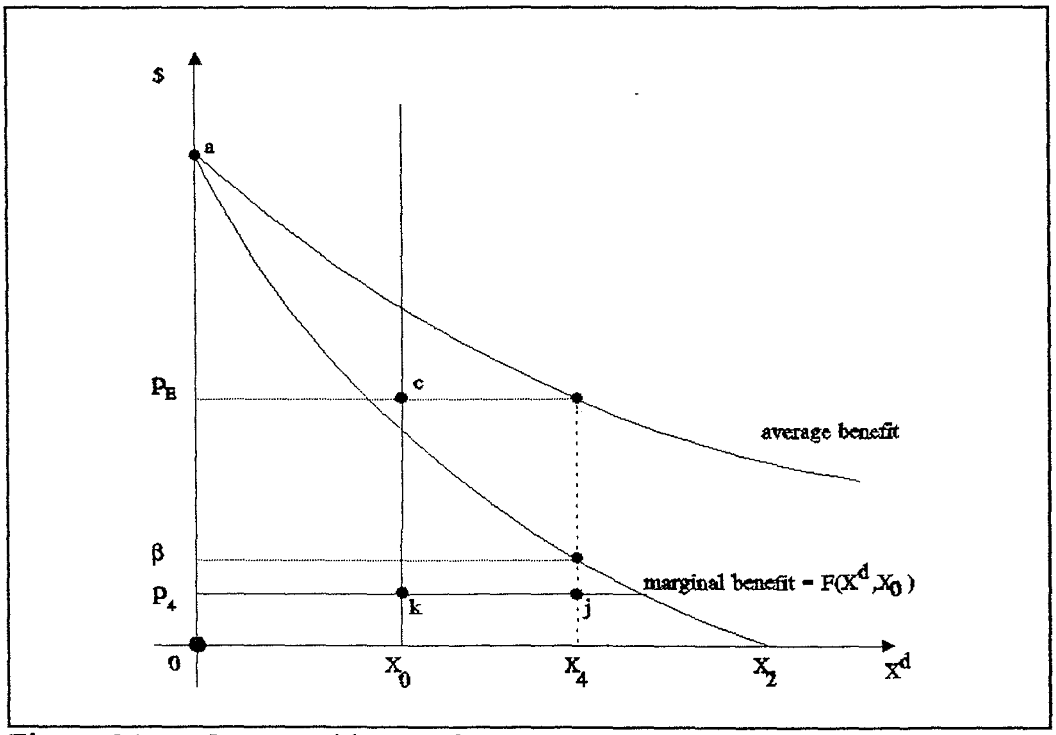


**Figure 26** Lottery with entry fee

Solving this series of equations yields the equilibrium result:

$F(X_4,X_0).X_0 = P_4X_4$

which may be solved for $X_4$ in terms of the known parameters $X_0$ and $P_4$.

The resulting distribution of benefits is:

| | | | |
|---|---|---|---|
| Revenue | = | $P_4X_4$ | 5.30 |
| | = | area $0P_4jX_4$ | |
| E[CS] to successful applicants | = | $\{\pi. \int_0^{X_4} F(X^d,X)\, dX^d\} - P_4X_0$ | 5.31 |
| | = | area $P_4P_Eck$ | |
| E[CS] to unsuccessful applicants | = | $P_4(X_0-X_4)$ | 5.32 |
| | = | area $X_0kjX_4$ (N.B. this is a loss) | |
| E[B] | = | $\pi. \int_0^{X_4} F(X^d,X)\, dX^d$ | 5.33 |
| | = | area $0P_EcX_0$ | |

Inspection of Figures 25 and 26 reveals that, for any positive price less than the efficient price, an entry fee lottery is more efficient than a success fee lottery, and both are intermediate on efficiency grounds between efficient pricing and a pure lottery.

The efficiency costs and benefits of the mixed lotteries (relative to pricing and efficient pricing) are dependent upon the levels of the fees imposed.

## 5.6 Comparison of allocation methods

Figure 27 illustrates all possible price/lottery combinations, and allows comparison of benefit measures under the pure and mixed lottery and pricing strategies. The benefit measures are provided in Table 4.

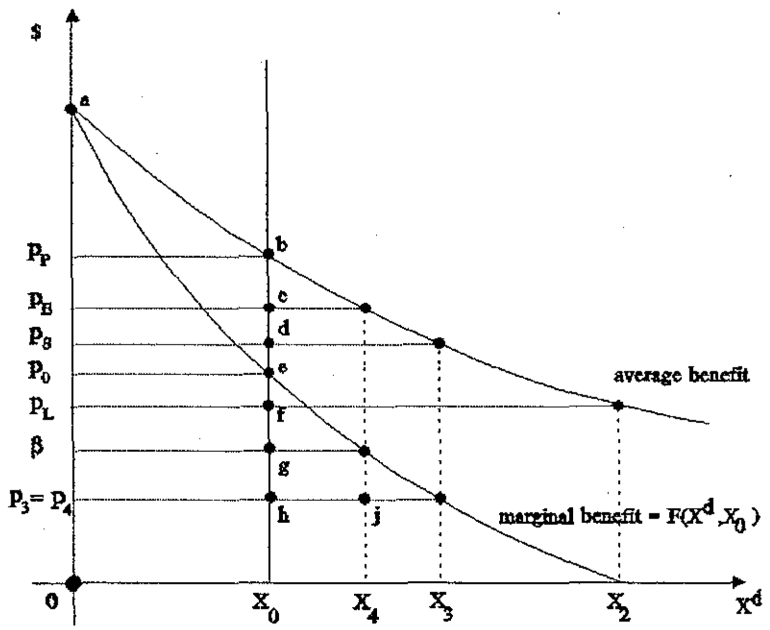


**Figure 27** Comparison of mixed price/lottery allocation methods

Average benefits under pricing are $P_P$. Under a pure lottery all people with marginal benefits from consumption greater than zero have an incentive to enter the lottery. These people have average benefits equal to $P_L$. Since $P_L$ is less than $P_P$ for any negatively sloping demand curve, the lottery is less efficient than competitive pricing.

Lotteries which employ either entry or success fees rank between competitive pricing and the pure lottery on the efficiency criterion. For a given fee ($P_3$ in Figure 27) expected per-capita benefits are $P_E$ and $P_S$ respectively. The entry fee is expected to be more efficient than the success fee. As the fees increase, total benefits increase until efficient allocations occur when fees are set equal to the competitive price.

**Table 4** Benefit measures for price/lottery rationing methods

| Benefit measure | Allocation scheme | Expected benefits | Rank |
|---|---|---|---|
| | Pricing | $P_P.X_0$ = area $0P_PbX_0$ | 1 |
| Total | Lottery | $P_L.X_0$ = area $0P_LfX_0$ | 4 |
| Benefits | Entry fee lottery | $P_E.X_0$ = area $0P_EcX_0$ | 2 |
| | Success fee lottery | $P_S.X_0$ = area $0P_SdX_0$ | 3 |
| | Pricing | $P_0.X_0$ = area $0P_0eX_0$ | 1 |
| Revenue | Lottery | zero | 4 |
| | Entry fee lottery | $P_4.X_4 = \beta.X_0$ = area $0\beta gX_0$ | 2 |
| | Success fee lottery | $P_3.X_0$ = area $0P_3hX_0$ | 3 |
| | Pricing | $(P_P-P_0).X_0$ = area $P_0P_Pbe$ | 4 |
| Consumer | Lottery | $P_L.X_0$ = area $0P_LfX_0$ | 1 |
| Benefits | Entry fee lottery | $(P_E-\beta).X_0$ = area $\beta P_Ecg$ | 3 |
| | Success fee lottery | $(P_S-P_3).X_0$ = area $P_3P_Sdh$ | 2 |

Notes:
1. Since $\beta.X_0=P_4.X_4$, area $0\beta gX_0$ equals area $0P_4jX_4$
2. The consumer benefit rankings are derived by appeal to the fact that the average benefit curve is less steep than the marginal benefit curve (constant crowding demand curve for the rationed quantity) whenever the marginal benefit curve is negatively sloped, hence $P_P-P_0 < P_E-\beta < P_S-P_3 < P_L-0$.
3. The fee level is identical for entry fee lotteries and success fee lotteries.

For these four allocation schemes the efficiency and revenue rankings are identical, and are the reverse of the consumer benefit rankings. Hence resource suppliers wishing to maximise profits will prefer the competitive pricing scheme to any of the lottery schemes, while (risk-neutral) consumers would prefer a pure lottery which is inefficient, but which ensures consumers obtain all the benefits produced.

### 5.6.1 The linear case revisited

By applying the definitions of total benefits for each rationing mechanism to a specific functional form it is possible to identify the efficiency costs of the mixed lottery/price allocation mechanisms relative to the pure lottery and pure pricing.

For the linear constant crowding demand function for capacity $X_0$, $P=a+bX^d$ (where $b<0$) the total (expected) benefits from price and lottery allocation are, respectively:

$$B_P = aX_0 + (bX_0^2)/2 \qquad 5.34$$

$$E[B_L] = (aX_0)/2 \qquad 5.35$$

Applying the definitions of Equations 5.29 and 5.33 to the linear demand curve, expected benefits from a success fee lottery are:

$$E[B_S] = (a+P_3)X_0/2 \qquad 5.36$$

while expected benefits from an entrance fee lottery are:

$$E[B_E] = aX_0\{1 + b/[2(P_4/X_0-b)]\} \qquad 5.37$$

$$\{\text{since, } \pi = (P_4 - bX_0)/a\}$$

$$= X_0a(2P_4-bX_0)/[2(P_4-bX_0)]$$

Substituting a price of zero for $P_3$ and $P_4$ confirms that one polar outcome of the mixed lotteries is identical to the pure lottery case. Setting Equations 5.36 and 5.37 equal to Equation 5.34 and solving for $P_3$ and $P_4$ yields: $P_3 = P_4 = a+bX_0$, which, by definition, is equal to the price needed to clear the market (the efficient price) with pure price rationing. In these cases, the probability of success in the lottery is unity and the mixed cases collapse into pure price rationing. Appropriate choice of $P_3$ or $P_4$ yields any desired level of total expected benefits between the polar cases of pure price and pure lottery rationing.

The question now arises as to why one would prefer either a success fee or an entrance fee lottery over the other. One likely reason for adopting either of these rationing mechanisms is to earn revenue (cost recovery) while offering the most equal opportunity allocation mechanism compatible with the revenue objective. It is therefore instructive to compare the efficiency and equity outcomes of the two schemes when prices are set to obtain the same level of revenue.

Equations 5.34 through 5.37 may be used to calculate the efficiency costs of mixed rationing schemes. These are:

$$B_P - E[B_S] = X_0(P_0-P_3)/2$$

$$B_P - E[B_E] = bX_0^2(P_4-P_0)/[2(P_4-bX_0)$$

which are positive whenever $P_3$ or $P_4$ are less than the market-clearing price ($P_0$). In other words, there is an efficiency cost to implementing either of the mixed allocation schemes.

Equations 5.27 and 5.30 yield the following condition for equality of revenue:

$$P_3 = aP_4/(P_4 - bX_0) \qquad 5.38$$

Rearranging Equation 5.38 and subtracting $P_4$ from each side provides a measure of the difference in prices necessary to generate identical revenue.

$$P_3 - P_4 = P_4(a+bX_0-P_4)/(P_4-bX_0) \qquad 5.39$$

Equation 5.39 is always greater than zero when $P_4$ is less than the market-clearing price, indicating that (for the linear demand case) a success fee lottery will always have to charge a higher fee than an entrance fee lottery in order to raise the same revenue (still assuming risk-neutrality on behalf of consumers). The entrance fee lottery is therefore more equitable in the sense that, because the fee is lower, more people have the option of entering the lottery than would be willing to pay the fee in a success fee lottery.

Substituting Equation 5.38 into the demand function and solving for $X_3$, the number of people entering the success fee lottery, yields:

$$X_3 = aX_0/(P_0-bX_0) \qquad 5.40$$

$$= X_4$$

$$\{\text{since } X^d = (P-a)/b = H(P,X)$$

$$X_4 = H(P_4/\pi, X_0)$$

$$\pi = X_0/X_4\}$$

The same number of people enter each type of mixed lottery.

Substituting the value of $P_3$ from Equation 5.38 into Equation 5.36 and rearranging yields:

$$E[B_S] = aX_0(2P_4-bX_0)/[2(P_4-bX_0)] \qquad 5.41$$

$$= E[B_E] \qquad \text{(from Equation 5.37)}$$

With a linear demand function and risk-neutrality there is no difference in expected efficiency between success fee and entrance fee lotteries which raise an equal amount of revenue. Since the two mixed lotteries provide identical revenue and expected total benefits, they must also provide identical expected aggregate consumer benefits. The entrance fee lottery must therefore provide greater expected benefits to those who obtain access to the resource.

## 5.7 Conclusions

This chapter has reviewed price rationing, lottery rationing, and two approaches which combine price and lottery rationing. It was found that pure pricing is the most efficient of these rationing mechanisms, while the pure lottery ensures equality of opportunity. Much of the efficiency gain obtained by implementing pure price rationing (*vis a vis* open-access) is captured by facility operators. While pure lotteries are not as efficient as pure pricing, consumers may prefer them because they can yield higher consumer benefits than pure pricing. Consumers may also view lotteries as being inherently fairer than pricing. Alternative outcomes may be obtained by combining pricing and lottery mechanisms, either through a success fee lottery, or through an entrance fee lottery.

Once the demand function is known it is possible to evaluate relative benefits of alternative rationing schemes for the many different benefit categories. These procedures were illustrated using the simple linear demand function. In order to evaluate lottery related mechanisms it was necessary to address consumer attitudes to risk. Here it was assumed that consumers are risk-neutral, and expected values were consequently used for all benefit measures.

It was found that any value of total benefits or revenue between the polar extremes could be attained by selection of appropriate fees in association with a lottery. For the linear case with any level of revenue generation, the success fee is higher than the entrance fee, the same number of people enter each type of lottery, and the two mixed lottery types provide identical aggregate consumer benefits and total benefits.

This chapter has presented an analysis of the choice of rationing mechanisms. In order to make progress it was necessary to make some rather heroic assumptions. The boldest of these are assumptions of zero transaction costs and risk-neutrality. The findings were illustrated with respect to a hypothetical constant crowding demand function. It is not possible to derive general rules regarding the relative benefits of alternative rationing mechanisms. Solution of real-world allocation problems will therefore depend upon obtaining knowledge of: transaction costs associated with each alternative, producer and consumer attitudes to risk, and the specification of the constant crowding demand function.

# CHAPTER SIX

# MEASURING DEMAND FOR CONGESTIBLE RESOURCES

## 6.1 Information needs

In order to allocate congestible goods efficiently, or to understand the efficiency implications of alternative allocation procedures, congestion-dependent demand information is needed. It is not possible to directly observe markets for different levels of congestion which exhibit a wide variety of prices, consequently estimation of constant crowding demand curves becomes an exercise in non-market valuation. Willingness to pay in terms of money, time, advance planning, or effort must be estimated as a function of the congestion parameter of interest (e.g. expected encounters, user density, etc.) and the amount of the good consumed. Alternatively, the quantity of use may be estimated as a function of price and congestion parameters.

## 6.2 Information sources

Several approaches have been developed for estimation of non-marketed demands. Those approaches which enjoy wide conceptual support, published applications, and are potentially applicable to measuring demand for congestible recreation resources include[1]:

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[1] Hedonic wage and price models enjoy wide conceptual and practical support. However, it is not theoretically possible to apply them in their pure form to valuing recreational resources. The hedonic travel cost method is an adaptation of the pure hedonic price method to allow its application to this class of valuation problem.

a) Travel cost method

   (i) Simple travel cost method

   (ii) Multiple site travel cost method

   (iii) Generalised travel cost method

   (iv) Hedonic travel cost method

   (v) Characteristics approach to demand estimation

   (vi) Gravity models

b) Contingent valuation method

c) Combined travel cost and contingent valuation approach

This chapter investigates the ability of each of these methods of non-market valuation to measure congestion-dependent demand. No attempt is made to describe the methods in detail or provide critical analysis of them *per se*, since there are now several books published that do this (Braden and Kolstad, 1991; Cummings, Brookshire and Schulze, 1986; Johansson, 1987; Mitchell and Carson, 1989; Peterson, Driver and Gregory, 1988) as well as numerous articles that have appeared in academic journals addressing specific issues related to the methods. This chapter provides an investigation of the applicability of the various extra-market demand estimation methods for measuring demand as a function of an endogenous site quality variable, in this case user density.

### 6.2.1 Simple travel cost method

The simple, or single-site, travel cost method can be applied to value resources in their existing states. The underlying concept is that the number of visits to a site is determined by the sum of travel cost and site entrance fee. By comparing visit rates for potential site users facing different travel costs it is possible to estimate how behaviour changes as costs change and therefore map out a demand curve for the site.

The simple travel cost method may be applied to individuals or to groups, the group case often being referred to as "the Clawson approach" after the first person to apply the method (Clawson, 1959). Under the group approach the potential site user population is divided into zones based upon residential location. Visits per capita for each zone is then used as the dependent variable in an estimated function relating behaviour to travel cost. Individual travel cost approaches measure number of visits per individual. The individual approach is more efficient and more robust in allowing estimation of the impacts of socio-economic and other variables on facility use (Brown and Nawas, 1973; Gum and Martin, 1975). It requires either collection of data from people who do not use the facility, as well as those who do, to obtain an unbiased model, or use of advanced statistical techniques[2] to account for truncation effects which result from sampling only site users. The individual travel cost model also requires more advanced statistical analysis because the number of trips an individual makes to a site is a discrete number, whereas the average number of trips for a large population can be any real number. The following discussion addresses the zonal approach to application of the travel cost method, but the arguments apply equally to the individual approach.

Demand theory suggests that demand for any good is influenced by the prices of all goods. Unbiased estimates of value are therefore only obtained when prices of substitute sites are included as parameters in the demand function (Caulkins, Bishop and Bouwes, 1985; Kling, 1989). To account for the existence of

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[2] Techniques include: maximum likelihood estimation methods, random utility models, tobit models, and others (Smith and Desvousges, 1985; Fletcher, Adamowicz and Graham-Tomasi, 1990; Smith, 1988). Smith (1988) discusses this topic extensively.

substitute and complementary sites, more advanced forms of the single-site travel cost model (see, for example, Hof and King, 1982) estimate the primary stage of the model in the following form:

$$V_k = f(P_{1k}, P_{2k}, \ldots, P_{nk}, S_k) \qquad 6.1$$

where $V_k$ = visit rate to the study site by residents of origin zone k,

$P_{ik}$ = cost of visiting site i for residents of zone k,

$S_k$ = A vector of socioeconomic and other characteristics for residents of zone k.

The structure of the simple travel cost model implies that characteristics of all sites are fixed. This method is therefore unable to value characteristics (or changes in their levels). Initially, the fixed characteristics feature of the method was seen as a problem for resource valuation under conditions of congestion, especially in the context of revenue-based measures of value (Wetzel, 1977). The problem arose because the method did not produce a "market" demand curve, it did not predict the number of visits that would actually occur as site use costs were varied. When congestion exists at current use levels the simple travel cost method under-estimates use at higher prices. McConnell (1980) and Anderson (1980) showed that the simple travel cost method estimates a single constant crowding demand curve, and therefore yields an appropriate measure of value of a site at its existing level of use.

The simple travel cost method is easily applied, requiring use data from only one site and information on the characteristics of potential site user populations. However, there is no way of using the method to map out more than a single constant crowding demand curve, unless it is possible to conduct longitudinal studies in which all other site and potential user characteristics are constant, but in which target facility use levels change (say in response to a growth of population). This situation is most unlikely to occur in practice. Consequently, the simple travel cost method is unable to offer sufficient information for management[3] of congestible resources.

### 6.2.2 Multiple site travel cost method

It is possible to value a system of facilities, and to value additions or deletions to that system by extending the travel cost analysis to many sites (Burt and Brewer, 1971; Cicchetti, Fisher and Smith, 1976). By assuming that any of the sites attains the characteristics of any other site it is possible to value new sites, site closures, and some changes in site attributes. This approach could be used to map constant-crowding demand curves for any of a series of sites, within the range of observed densities.

Existing site use data are used to estimate the following series of equations which describe use of all sites in their present states:

$$V_{ij} = f_i(P_{1j}, P_{2j}, P_{3j}, \ldots, P_{nj}, \text{Others}) \qquad 6.2$$

where $V_{ij}$ = per-capita visits to site i by residents of region j,

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[3] Because the simple travel cost method estimates only one constant crowding demand curve it is unable to be applied to accurately predict actual use levels as a function of price, or to measure consumer benefits at different use levels to those currently existing. It is therefore not possible to use simple travel cost demand information to estimate use levels and their consequences (such as environmental impacts), to estimate revenue or costs as functions of price, or to identify efficient prices and/or use levels.

$P_{kj}$ = minimum cost of visiting a site of type k for residents of region j,

$f_i$ = a site-specific relationship between per-capita visitation rate, prices, and other (socio-economic) variables.

Equation 6.2 is used to map out the demand curves for each of the sites by systematically varying the cost of using each site and predicting visit rates from each zone over a range of prices. When each site is unique the $P_{kj}$'s refer to individual sites, but when several similar sites exist people are assumed to use the cheapest site of any type and the $P_{kj}$'s refer to the minimum cost of using a site of that type.

Suppose that all sites are unique (i.e. there is only one site of each type) and that management changes are implemented at Site 1 so that it becomes identical to Site 2. After the changes are implemented the cost of reaching a type 1 site is infinite, since Site 1 is no longer available in its type 1 form. However, Site 1 is now available as a type 2 site, reducing the cost of this type of site for <u>some</u> individuals[4]. Some people who previously visited Site 2 will now visit Site 1. Further, people who did not visit either Site 1 or Site 2 may now choose to visit Site 1 because the reduction in relative price makes activity type 2 relatively more attractive than other activity types. Of course, people who previously visited Site 1 may still visit it, may redistribute use to other sites, or may not use any site. It is possible that demand for all sites may change because of changes implemented at one site.

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[4] Some people (those who live closer to Site 2 than to Site 1) will still find it cheaper to use Site 2 rather than Site 1 to obtain a type 2 experience, while others will now find it cheaper to use Site 1 to obtain a type 2 experience (those who live closer to Site 1 than to Site 2).

Even if interest is centred on demand for only one site, information is still required on the demand for the type of site into which it will be transformed to allow mapping of the demand curve for the site after the change in characteristics. For example, in the case where Site 1 is transformed to have characteristics identical to Site 2, the new demand for Site 1 is evaluated using Equation 6.3, in which the price of using Site 1 is infinite.

$$V_{1j} = f_2(\infty, P_{1j}, P_{3j}, \ldots, \text{Others}) \qquad \text{if } P_{1j} < P_{2j} \qquad 6.3$$

$$V_{1j} = 0 \qquad \text{otherwise}$$

More generally, the new demands are predicted using the revised parameters in the previously estimated model, i.e.

$$V_{ij}^{*} = f(P_{1j}^{*}, P_{2j}^{*}, P_{3j}, \ldots, P_{nj}, \text{Others}) \qquad 6.4$$

where $P_{kj}^{*}$ = the minimum cost of visiting a site of type k for residents of region j after the change in characteristics at the study site (Site 1).

The value of a change in characteristics at any one site may be estimated as the difference between consumer surplus at the site before and after the change (Samples and Bishop, 1985). In other words, welfare changes contingent upon changes in site characteristics may be evaluated using the demand curve for the site where the changes occur, there is no need to include demand impacts at other sites (Knetsch, 1977). However, a change in a site's characteristics entails at least two price changes[5]. Unless cross-price terms are identical for each pair of goods for

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5 The cost of visiting a site with the study site's original characteristics will increase for some people, while the cost of a visit to a site with the study site's final characteristics will decrease for some people.

which prices change, the change in consumers surplus is not independent of the order in which the prices are changed (Just et al., 1982; Hof and King, 1982). This path dependency problem means that the areas under demand curves "provide no information regarding the underlying change in utility" (Johansson, 1987: p.124). There is some evidence from empirical studies of inequalities in cross-price terms[6]. However, some authors argue that even when equality of cross-price terms does not exist the discrepancy between true and estimated changes in value will be small (Hof and King, 1982).

Use of the multiple site travel cost model to generate congestion-dependent demand functions is reliant upon the existence of several spatially separated sites with heterogenous crowding characteristics and which exhibit homogeneity of all other site characteristics. The identity of irrelevant characteristics requirement occurs because the means of valuing a change in characteristic (crowding) is to assume that the site under study becomes identical to an existing site. Consequently, use of the site with the new set of travel costs may be estimated using the existing set of site demand functions (Equation series 6.4).

If demands for sufficient sites, exhibiting diverse levels of crowding, are modelled it is possible to map constant crowding demand curves for every crowding level currently encountered over the range of sites. However, the homogeneity of other site characteristics requirement is not easily satisfied, and therefore presents a severe practical difficulty in applying this method[7]. Further, the importance of the cross-price term symmetry assumption is not fully understood.

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[6] For example, Cicchetti, Fisher and Smith (1976) and Hylland and Strand (1983, cited in Johansson, 1987) both found that symmetry conditions on cross-price terms were not satisfied.

[7] This difficulty should not be misinterpreted as a criticism of the multiple-site travel cost method *per se*, since the method was developed to value new sites and not to value site characteristics. The method does, however, present the possibility of valuing changes in site characteristics.

Samples and Bishop (1985) describe an alternative method for estimating the value of characteristic changes using the multiple-site travel cost model. A two-stage process is employed, with the first stage being application of the usual multiple site travel cost model to estimate consumer surplus for each of a set of sites which exhibit a variety of characteristics. In the second stage the impact of changes in characteristics is measured by fitting a model which specifies site consumer surplus as the dependent variable, and site characteristics as independent variables (Equation 6.5).

$$\text{Value of site } i = (Q_{1i}, \ldots, Q_{ki}, P_1, \ldots, P_n) \qquad 6.5$$

where $Q_{ji}$ = the level of characteristic j at site i, and

$P_m$ = the price of using site m.

This approach requires information on several sites to provide sufficient cases for statistical validity in the second part of the procedure, especially if there is a large number of characteristics. It can therefore only be expected to be applicable in a limited number of situations.

Estimates of the parameters associated with each characteristic are biased if relevant independent variables are excluded from the right hand side of Equation 6.5. Samples and Bishop (1985) provide a conceptual framework which indicates that all variables in Equation 6.5 should be included. However, this is not possible because doing so causes the number of equations to be less than the number of independent variables. The approach adopted by Samples and Bishop is to exclude prices from Equation 6.5. Further, even if prices could be included, there is a problem with determining what the price of use for any site is when users face a range of prices, as recognised in the approach of stage one in this method. This technique can therefore only be considered to be an *ad hoc* method for estimating the impacts of characteristic changes.

### 6.2.3 Generalised travel cost method

The generalised travel cost method[8] (Vaughan and Russell, 1982; Smith, Desvouges and McGivney, 1983; Smith and Desvouges, 1985) is designed to enable valuation of site attributes. The model may be estimated in either a single-stage or a two-stage structure. The two-stage model first estimates a travel cost model using data from several sites. The visitation rate model for each site uses own-price as an independent variable, and does not incorporate the prices of substitute sites. The functional form of the visitation rate model is identical for each site, but the coefficients on the parameters are not. For example, a linear form of the visitation rate model would be:

$$V_{ij} = a_i + b_i P_{ij} \qquad 6.6$$

where $a_i$ and $b_i$ are parameters to be estimated for each site.

The coefficients estimated in the first stage describe how use varies between sites, assuming no costs of site use ($a_i$) and how use varies for each site, depending on the cost of using that site ($b_i$). The coefficients of the first stage should therefore reflect site attractiveness, and consequently be dependent upon site characteristics. In the second stage of the two-stage generalised travel cost model, site characteristics are used as independent variables in models that estimate the coefficients (the $a_i$'s and $b_i$'s) derived in the first stage.

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8 Mendelsohn and Brown (1983) refer to the generalised travel cost model as the "own price/quality model". Many authors refer to it as the "pooled demand model" or the "varying parameter model".

$a_i = f(Z_{i1},...,Z_{in})$

$b_i = g(Z_{i1},...,Z_{in})$

where $Z_{ik}$ is the $k^{th}$ characteristic of site i.

Substituting the second stage equations into the first stage equation yields:

$$V_{ij} = h(P_{ij},Z_{i1},...,Z_{in}) \quad 6.7$$

Because the functional form for the first stage is identical for all sites, and the second stage models are site-independent, Equation 6.7 is site-independent. It is a general model that explains use of any site as a function of its own price and characteristics. Single-stage models estimate the reduced form model of Equation 6.7 directly (see, for example, Loomis, 1989).

The two-stage generalised travel cost model does not include prices of substitute sites. This results in logical inconsistencies because the user is able to choose the desired level of quality from several sites, but does not use the cost of other sites in determining the optimal use strategy (Mendelsohn and Brown, 1983). The only cases in which applications of this model are theoretically defensible therefore occur when consumers have no choice of quality. In other words, quality is homogeneous across sites, or the prices of substitute sites are so high that none are used. In these cases the assumption that quality of substitute sites does not influence the consumer's decision, implicit in the first stage, is valid, however there is also no variation in quality to value in the second stage.

Some authors have included quality and prices of substitute sites in reduced form models (e.g. Menz and Wilton, 1983; Loomis, 1989), however quality and prices for all sites cannot be included as independent variables in the same regression because of matrix inversion impossibilities (Samples and Bishop, 1985). One variable is used to represent the "availability" of substitute sites. The problem with this approach lies in constructing a single item index to satisfactorily represent the availability of several sites which display a range of characteristics and prices. The information necessary to construct this index is the target of the valuation exercise, namely the marginal values of characteristics, and is therefore unavailable.

Kling (1987) reports use of a stacked regression technique to incorporate substitute site prices. However, she claims that it is not possible to include variables representing quality of substitute sites because that would eliminate the quality variation necessary to estimate the demand functions (Kling, 1987). Omission of substitute site quality variables does not present any error in estimates of welfare change from a quality change at a single site (Kling, 1989).

### 6.2.4 Hedonic travel cost method

The hedonic travel cost method (Brown and Mendelsohn, 1984) may be used to value attributes that are obtained as part of a package containing many attributes. It avoids the requirement of the multiple site travel cost method of having several substitute sites which exhibit homogeneity of all characteristics apart from the characteristic being valued. The hedonic travel cost method derives a marginal cost function for attributes from a comparison of the costs of visiting sites with heterogeneous attributes. Site choices for people facing different cost structures are then used to map out demand curves for attributes. If supply is inelastic and demand is spatially diverse (implying different marginal costs for individuals) the identification problem inherent in other hedonic models is not encountered. These conditions are often characteristic of outdoor recreational facilities.

The hedonic travel cost method introduces additional estimation problems beyond those encountered in other travel cost approaches. This method is sensitive to assumptions, and does not appear to give reliable estimates of value. For example, different methods of measuring site characteristics "dramatically altered the estimated characteristic demand functions" and "[t]he treatment of observations with negative prices also had a large effect on the estimated demand and inverse demand models" (Smith and Kaoru, 1987).

In reviewing the status of the hedonic travel cost approach Smith and Kaoru (1987) conclude that the method has not reached the stage of development where it can be considered a straight forward application of the underlying theory. Consequently, while this approach is a potentially valuable method of valuing recreation site characteristics, including congestion, it is not currently available for this purpose.

### 6.2.5 Characteristics approach to demand estimation

Using Lancaster's (1971) characteristics approach to demand theory, Morey (1981) and Greig (1983) have developed modified versions of the travel cost method capable of valuing changes in site characteristics.

Greig's method compares the characteristics of each site with the costs of site use (travel and other costs) to construct characteristic possibility frontiers for potential site users at a variety of locations. Observations of site use and activity budgets coupled with an assumed functional form for site users' utility functions are used to estimate specific utility function parameters. The estimation procedure entails trial and error to find the set of parameters yielding the closest predictions of observed behaviours.

Site demand curves can be estimated by systematically varying the cost of using a site. Changes in price result in changes in the characteristic possibility frontier. Estimates of site use are made by maximising the previously estimated utility function subject to the characteristic possibility frontier which prevails at each price.

Changes in site characteristics result in new characteristic possibility frontiers, and may be valued by re-estimating site demand contingent upon the new characteristic possibility frontier, utilising the previously estimated utility function and observed budget.

Greig's application of this model was only intended to be illustrative of the approach, and was successful to the extent that he was able to obtain estimates of the value of changes in characteristics. There was no attempt to verify results[9], so it is not possible to draw any conclusions with respect to the ability of this method to accurately measure the value of characteristics. However, several underlying assumptions need further investigation before the method can be accepted uncritically. First, Greig assumed a fixed budget for the study activity, implying that changed characteristics do not result in a change in total expenditure on the activity, which is contrary to received economic theory. Second, a Cobb-Douglas utility function in characteristics space was assumed. While the Cobb-Douglas form may be appropriate, the strength of this assumption, the predictive power of other functional forms, and sensitivity to functional form were not tested. Third, Greig recognised that there are problems in measuring some types of characteristics. There remains the possibility that characteristics such as aesthetic beauty may not be delivered in proportion to the amount of use of a recreation site. This final

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[9] There was no attempt to compare values to those obtained from applications of other non-market valuation methods, or to apply the approach to make behavioural predictions which could be tested.

concern is irrelevant if the analyst wishes only to estimate congestion-dependent demand functions and does not want to value other site characteristics which exhibit such measurement difficulties. The first two assumptions do, however, pose real concerns for estimation of congestion-dependent demand functions.

Morey's model assumes a fixed activity budget and employs prices numerated in time units in a model that describes how the time budget is allocated amongst a range of substitute sites. Morey uses a second-order approximation to a general, twice differentiable utility function which is additive and homothetic. The utility obtained from each site is determined by the amount of use of that site, the characteristics of the site, and the individual's ability to use site characteristics.

Data from a cross-sectional survey of skiers were used to estimate the utility function, using maximum likelihood methods to predict site share equations as functions of the utility function parameters. Incorporation of new prices and/or site characteristics could then be used to determine characteristic-dependent demand functions for each site in the manner employed by Greig.

The characteristics theory of demand estimation provides a grounding in utility theory for valuation of characteristics. It is necessary to identify the underlying utility functions for policy determination or evaluation using this approach. Doing so requires the analyst to make strong assumptions about the nature of utility functions, specifically with respect to separability of utility for the activity under study and with respect to functional form for the utility function for that activity. Mendelsohn and Brown (1983) cite three major problems with the household production function (characteristics) approach to demand estimation. These are: econometric difficulties, the assumption that consumers share a common production function, and the extensive information needs - including a complete list of commodities demanded by resource users. These difficulties lead to the conclusion that "the tool is an unnecessarily cumbersome approach to measure the value of sites or their qualities" (Mendelsohn and Brown, 1983 p.611). Further, until the necessary assumptions can be validated and/or sensitivity to functional form is shown to be inconsequential it is not possible to determine the validity of applying the characteristics approach to demand estimation.

### 6.2.6 Gravity models

Ewing (1980) summarises three types of gravity model that have been used to model recreational trips, and may therefore be used to value recreation facilities. These models all predict the number of trips to a site from origin zones as a function of origin zone population, travel cost, and attractiveness of the site. The simplest model (the unconstrained gravity model) does not account for costs or attractiveness of substitute sites. A more advanced model (the origin-constrained gravity model) partly addresses the existence of substitutes by "assum[ing] that a fixed number of trips emanate from [each origin] irrespective of the number, attractiveness, and accessibility of the destinations. ... it assumes that the proportion of trips from [origin] i terminating at [site] j is a function of the attractiveness and accessibility of j in relation to the attractiveness and accessibility of all other destinations in the system" (Ewing, 1980 pp.3-4). Ewing argues that this approach is unacceptable for modelling discretionary trip behaviour, which requires a supply-generated participation model. This model takes the form:

$$t_{ij} = t_i m_{ij} \qquad 6.8$$

where $t_{ij}$ = the number of trips from origin i to destination j,

$t_i$ = the number of trips emanating from origin i irrespective of destination,

$m_{ij}$ = the proportion of trips originating in i that go to j.

In this model $t_i$ is the trip generation element and $m_{ij}$ is the trip distribution element[10]. In general, these models take the form:

$$t_i = N_i G_i f_1[\Sigma A_k f_2(C_{ik})] \quad 6.9$$

$$m_{ij} = A_j f_2(C_{ij})/[\Sigma A_k f_2(C_{ik})] \quad 6.10$$

where $G_i$ = intrinsic per capita trip generation potential of origin i (i.e. some function of socioeconomic characteristics of origin zone i),

$f_1$ = the "supply-generated participation" effect;

$N_i$ = population of zone i,

$C_{ij}$ = cost of return travel from origin i to destination j,

$f_2$ = some function expressing the number of visits to an individual site, dependent upon the cost of visiting that site, and

$A_j$ = a measure of the attractiveness of site j.

Operationalisation of this model requires estimation of $G_i$, $A_j$ and the functions $f_1$ and $f_2$. Examples of application of gravity models to valuation of recreational resources include Cesario and Knetsch (1976) and Chan and Carroll (1985).

This theoretical structure does not account for differences between origin zones in the availability of substitute activities in the trip generation section of the

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10 These are termed the accessibility and allocation functions respectively by Chan and Carroll (1985).

model, leading to the conclusion "the absence of such a term should evoke some doubt about the validity of the parameters estimated in existing generation models" (Ewing, 1980 p.8). This problem is overcome in the model adopted by Chan and Carroll (1985), which incorporates attractiveness and costs of all sites in the trip generation part of the model.

Gravity models are expanded generalised travel cost models with a pre-specified relationship amongst some of the parameters. To see this, Equation 6.8 may be written in a general form (Equation 6.11) that shows that it has a specification that includes all the parameters of the generalised travel cost model (own-price and quality attributes), plus the prices and attributes of substitute sites.

$$V_{ij} = f(C_{i1}, \ldots, C_{ij}, \ldots, C_{in}, A_1, \ldots, A_n, G_i) \qquad 6.11$$

Therefore, in theory, this approach avoids the substitute problem which precludes the generalised travel cost model from being used to value quality changes.

There is no theoretical justification for the specific form of gravity models. One problem with restriction of functional form is that it may result in less explanatory ability than models which allow selection of functional form on statistical grounds. This may be one reason for the finding that "the goodness of fit of such models, calibrated using real world data, leaves a lot to be desired. ... models do not fit the data as well as is necessary to place faith in the validity of the model. ... At present, then, there are sufficient sources of misspecification of spatial interaction models to be wary about placing strong reliance on exact parameter estimates" (Ewing, 1980 pp. 18-19).

Apart from this practical concern, there are two major theoretical concerns with gravity models. First, is the need to estimate a measure of site attractiveness prior to estimation of the model. In this sense gravity models embody similar problems to the generalised travel cost model. The impact of site characteristics on site attractiveness is the desired end product of the exercise and cannot be an input to it. Typically, gravity models use researcher-defined proxies for site quality, such as park area, in order to estimate site demands. Estimation of constant crowding demand curves requires a model that can predict the impact of crowding on site attractiveness and thereby on site demand. The only solution is to estimate the attractiveness scores endogenously and then use them as dependent variables in a separate model relating them to site characteristics[11]. A method for endogenous estimation of attractiveness scores is provided by Baxter (1979). Second, is the inability to estimate models that include both quality and price variables as exogenous terms, as discussed in the generalised travel cost section.

### 6.2.7 Contingent valuation

Contingent valuation may be applied to allow either direct estimation of welfare changes and/or estimation of site demand curves. The technique asks survey respondents to either value their change in welfare directly, or to indicate their purchasing behaviours given a purchase price for the good being valued.

The first applications of the contingent valuation method required respondents to nominate the value of welfare changes (Davis, 1963). However, it is becoming increasingly common to use price as an independent variable, and to ask survey respondents to indicate whether they would purchase a specified

[11] Assuming that characteristics other than crowding also impact on site attractiveness, otherwise the crowding measure may enter directly.

environmental commodity at a specified price[12], or to ask how much use of a facility the respondent would make (if any), contingent upon having to pay a specified use fee. This independent-price approach is more like everyday market transactions that survey respondents are familiar with than the original (dependent-price) contingent valuation approach. Consequently, this "quantity-estimating" form of the contingent valuation method is more likely to satisfy Cummings *et al.*'s (1986) reference operating conditions for successful application of the contingent valuation method than the "value-estimating" form.

In the value-estimating form, contingent valuation of a quality change entails asking survey respondents to reveal their maximum willingness to pay to obtain a nominated improvement in quality, or minimum compensation demanded to agree to a nominated decrease in quality[13]. Quantity of use at the new quality level is not normally estimated. This approach measures relative total values of alternative states of the resource. These relative values represent the difference in areas under compensated constant crowding demand curves, and do not provide information on the location of those constant crowding demand curves. If sufficient quality changes are evaluated this approach may be used to estimate a relationship of the form:

$$\$_{CV} = f(Q: Q_0) \qquad 6.12$$

where $\$_{CV}$ = social compensating variation of a change to quality level Q,

$Q_0$ = current site quality[14].

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[12] Mitchell and Carson (1989) refer to this as the referendum approach.

[13] Assuming that Hicksian compensating variation is the target measure of welfare change.

[14] In order to provide compensating measures of value, the function f measures changes in value relative to the *status quo*, $Q_0$. Therefore, $Q_0$ is fixed, while Q is variable.

This approach is not amenable to estimation of constant crowding demand curves. Some authors have attempted to use contingent valuation-like approaches to map ordinary demand curves (e.g. MacCrimmon and Toda, 1969; Sinden, 1974; Findlater and Sinden, 1982) by using hypothetical markets to map indifference curves, which may then be combined with budget data to estimate demand curves. The methods used encountered some conceptual difficulties, which can be overcome (Bennett and Smith, 1985); some conceptual problems which cannot be easily resolved, most notably allocation of budget to a sub-set of utility-yielding activities and a cardinal utility measurement requirement (Bennett, 1987); and severe practical difficulties. The practical difficulties involve the requirement for each survey subject to undergo a lengthy, repetitive process to identify indifference curves, even for a small number of goods (Findlater and Sinden, 1982). Survey respondents are typically unwilling to subject themselves to this type of experience, and those who do quickly tire of it. Consequently, to the author's knowledge, there have not been any recent applications of these indifference curve-mapping approaches.

To simplify the valuation procedure for respondents, analysts are increasingly adopting contingent ranking, dichotomous choice and multinomial (independent-price) techniques for application of contingent valuation. In these cases individuals are not required to furnish a full preference map, or identify relative values. The aggregate demand curve is estimated from the reported behaviours of many respondents who face a variety of combinations of independent variable values. Dichotomous choice approaches ask <u>whether</u> the behaviour would occur or not (would you visit this art gallery today if it cost you $2 to get in?), while multinomial response models ask <u>how often</u> the behaviour would occur (how many days would you use this skifield this winter if the tow fee was $40 per day?).

Contingent ranking approaches ask respondents to nominate their preferred price/quality combinations from a limited set of choices.

The dichotomous and multinomial approaches may be used to estimate constant crowding demand curves by including quality (total use, user density, encounters, etc.) as an independent variable, along with price. The questions posed to survey respondents take the form: how much use would you make of facility X if user density was Y and price was Z? For example, how many days would you use this ski field this winter if tow queues averaged 10 minutes and the tow fee was $40 per day? Hence, aggregation of individual responses to a variety of fee/quality combinations allows estimation of aggregate demand curves with the following form:

$$q = f(\$,Q) \qquad 6.13$$

where q = amount of use of the facility,

$ = facility use fee,

Q = total amount of use (or other crowding measure, e.g. average time in tow queues).

Clearly, Equation 6.13 is the constant crowding demand curve specification. Logit and probit models are commonly used for analysis of dichotomous and multinomial choice models.

Whereas the value-estimating and contingent ranking forms of the contingent valuation method yield Hicksian estimates of welfare change, the dichotomous and multinomial choice, quantity-estimating forms yield estimates of Marshallian demand curves. Hicksian measures are the theoretically preferred alternative, as they allow application of the Kaldor-Hicks criterion. The problems arising from use of Marshallian measures in place of Hicksian measures are addressed in the following chapter.

The contingent valuation method is theoretically applicable to any valuation scenario, as long as survey respondents are willing to comply with the rules of the game; placing themselves in the contingent situation described to them, carefully evaluating their optimal behaviours under those circumstances, and reporting those behaviours honestly.

There is a growing body of evidence on the ability of the contingent valuation method to provide meaningful measures of value for extra-market resources. These studies generally take one of two forms, they either compare the results of contingent valuation studies with the results obtained from other types of non-market valuation studies of the same resource (convergent validity), or they compare the results of contingent valuation studies with the results of simulated market studies (criterion validity). Simulated markets are markets in which real resources change hands in order to obtain access to the (excludable) good being valued. A further area of research has concentrated on measuring the degree to which people free-ride in contingent valuation settings.

Both of the validation approaches are limited in their applicability. Comparative studies are restricted to goods and services which may be valued by more than one method, and for which the different methods can be used to value identical components of total value. For example, a travel cost method/contingent valuation method comparison may not be possible if people hold significant option, bequest, or existence values for the resource being valued. These values would not be measured by the travel cost method (since it measures use values only), but it may not be possible to exclude them from some forms of contingent valuation estimates of value[15]. Simulated market studies can only be conducted on goods and services which are excludable (quasi-private). There is an open question over whether the results of such studies can be applied to the many non-marketed and public goods and services which are not excludable[16].

Mitchell and Carson report that "Overall, the comparisons between true payment conditions and those which encourage free riding suggest that under experimental conditions free riding accounts for a modest downward bias in the [willingness to pay] amounts of about 10 to 30 percent" (Mitchell and Carson, 1989:150-151). It should be noted that these results were obtained from value-measuring approaches to contingent valuation and that "the discrete-choice eferendum model was incentive-compatible ... This finding offers the possibility of framing contingent valuation questions so that they possess theoretically ideal and truthful demand-revelation properties" (*ibid*:151), suggesting that free riding should not cause significant difficulties in conducting contingent valuation non-market valuation studies, especially the quantity-estimating variants. Tests of contingent valuation studies failed to detect the presence of strategic behaviour (*ibid*, pp.165-168), suggesting that respondents to contingent valuation surveys will report their intended behaviours honestly.

There remains the issue of whether contingent valuation survey respondents fully evaluate their behavioural choices under the conditions detailed by the analyst. This issue is often referred to as one of hypothetical bias. Mitchell and Carson conclude: "laboratory and field experiments that compare the results obtained by

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15 Convergent validity studies do not prove that either study is accurate - both may be equally inaccurate!

16 Carson and Mitchell (1989:208) go further in claiming "Because the simulated market-hypothetical market studies are based on a consumer market model, their findings are not directly relevant to the use of CV studies to value genuinely public goods".

treatments using a hypothetical payment structure with those involving a nontrivial payment in real dollars ... revealed similar patterns of behaviour whether a hypothetical or a real payment was involved" (*ibid*:187).

The results of validation studies are reported by Cummings *et al.* (1986) and Mitchell and Carson (1989). After reviewing convergent validity studies, Mitchell and Carson conclude: "The large number of comparison studies show a reasonably high level of convergent validity", but they proceed to caution "the absence of a clear-cut criterion against which to compare [contingent valuation] values for public goods means that the validity of individual studies cannot be established in a definitive fashion" (*ibid*:208-209). The conclusion to be drawn is that, while it is not possible to definitively test whether contingent valuation values represent "true" values, the body of evidence suggests that people responding to contingent valuation surveys generally do evaluate the situation presented to them and report their intended behaviours honestly.

Application of the contingent valuation method to measure demand for (benefits obtained from) use of congestible facilities presents few conceptual difficulties. Survey participants could be presented with a variety of price/congestion level scenarios and asked to nominate their intended behaviour under those hypothetical scenarios. This approach could entail dichotomous choice by investigating whether use of the facility would be made during a time period which precludes the possibility of more than one unit of use per person. Alternatively, annual or seasonal use frequencies could be elicited by requiring respondents to nominate the number of trips they would make in the specified time period. Each approach allows constant crowding demand curves to be mapped and a congestion-dependent demand function to be estimated. To the author's knowledge, no studies of this type have been published.

If constant crowding demand curves *per se* are not of interest, efficient capacity under lottery allocation may be identified by use of value-estimating forms of contingent valuation. Survey participants are asked to nominate their maximum willingness to pay for use of a facility, during a nominated time period, under given congestion conditions. It is then possible to estimate mean willingness to pay as a function of congestion. Multiplying the number of users creating the level of congestion with the mean willingness to pay at the congestion level for all congestion (use) levels yields the relationship between total benefits and use level.

This approach is relevant only to estimating expected benefits under lottery rationing because it measures <u>mean</u> benefits under alternative congestion conditions, and not the <u>distribution</u> of benefits. The parameter estimated is the height of the average willingness to pay schedule at the point where marginal willingness to pay (the height of the constant crowding demand curve) is zero. The whole of the average willingness to pay schedule is mapped out by varying the congestion level (moving to a new constant crowding demand curve)[17]. The inability of this approach to appropriately recognise inframarginal surplus when more than one unit of use per time period is possible is noted by McConnell (1977:190).

Several authors have used contingent valuation to estimate the influence of congestion on willingness to pay, all have used willingness to pay as the dependent variable, rather than use frequency. Cicchetti and Smith (1973, 1976) estimated mean willingness to pay for a once-per-season wilderness outing. Independent

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[17] The location of constant crowding demand curves could be plotted by limiting the demand period so that only one unit of use per person is possible in that time. Information on maximum willingness to pay for use under stated congestion conditions could be used to determine the proportion of the population that would use the facility under a variety of price/congestion conditions. This procedure could therefore be used to derive the congestion-dependent demand function <u>for that period</u>. To the author's knowledge this has not been attempted.

variables included: length of the outing, numbers of camp and trail encounters, and the nature of those encounters (whether with parties on foot or with parties on horseback). This study found that encounter levels had significant impacts on mean willingness to pay. McConnell (1977) used on-site interviews to measure willingness to pay for beach use on the day of the interview. By measuring site congestion and other site quality variables McConnell was able to estimate a function relating "the average individual's surplus per day" to site use levels. The congestion variable was found to be significant at some beaches, but not at others. Walsh and Gilliam (1982) conducted a similar study on wilderness recreators, but extended their questioning to determine willingness to pay for the day's recreation at a variety of encounter levels. Number of encounters had a significant impact on willingness to pay, allowing the authors to estimate "the relationship of willingness to pay to number of persons encountered per day ... *for the representative individual*" (Walsh and Gilliam, 1982:6; emphasis not in original). Total willingness to pay at each facility use level was identified by multiplying mean willingness to pay at each level of congestion with total use[18]. The efficient capacity was identified as the capacity at which marginal willingness to pay was equal to marginal management costs.

The procedure adopted by Walsh and Gilliam does not identify efficient capacity. Firstly, it estimates willingness to pay <u>only</u> for those individuals currently using the facility. If a change in facility capacity brings about a change in expectations regarding the number of encounters while recreating at this facility it would also be expected to change the total number of users. If the people attracted to or displaced from the facility have different demand functions than current users who continue to use the facility then the Walsh and Gilliam estimates of mean willingness to pay as a function of congestion are wrong. Secondly, Walsh and

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18 A separate relationship was used to convert encounters to total daily use.

Gilliam estimate the mean height of constant crowding demand curves for current users. However, efficient allocation requires estimation of the mean heights of constant crowding demand curves out to the capacity consistent with the level of congestion implicit in each constant crowding demand curve. The Walsh and Gilliam procedure therefore underestimates mean willingness to pay for reductions in capacity and *vice versa*, when the use that does occur is allocated efficiently (say through price-rationing). Consequently, the Walsh and Gilliam approach is only appropriate for measuring expected benefits under rationing which allocates use randomly amongst existing users. These conditions could be satisfied under lottery rationing with a pre-requisite to entering the lottery being past facility use.

A variation on the methodology employed by Walsh and Gilliam was used by Walsh, Miller and Gilliam (1983) to estimate the impacts of queue length and skier density on mean willingness to pay for lift tickets at Colorado skifields. In this case "skiers reported values for each of the three levels of lift-line wait with each of the three levels of slope congestion, assuming that all other conditions remain unchanged, *including the number of days skied at the study sites per year*" (*ibid*:199; emphasis added). The assumption of constant use is equivalent to the focus on single day values employed in the other contingent valuation studies of congestion. Further, mean willingness to pay is estimated for all existing facility users, leading to identical conclusions regarding applicability to estimation of efficient capacity.

In summary, it can be seen that all existing empirical contingent valuation studies have adopted the value-estimating form of the method. This approach precludes the mapping of constant-crowding demand curves, but is potentially applicable to estimation of efficient capacities under a variety of rationing mechanisms. The existing empirical applications have all used flawed methodology to estimate efficient capacities. Use-estimating forms of the contingent valuation method have the potential for mapping constant crowding demand curves directly, and simplifying the estimation of optimal capacities. The cost of adopting the use-estimating forms is that Marshallian measures of welfare change are obtained, rather than the preferred Hicksian measures.

### 6.2.8 Combined contingent valuation and travel cost method

Combining the travel cost method with contingent valuation simplifies the requirements on survey respondents compared to a pure contingent valuation approach (see e.g. Narayanan, 1986). The combined approach is also applicable to valuing characteristics for cases where information is only available for a single site, greatly reducing data requirements in comparison with the multiple-site travel cost approaches.

In order to apply this approach the travel cost method is used to value a site in its existing state. A contingent market is then applied to reveal individual demands at a range of user densities, but with the present site use fee remaining unaltered. Application of the simple travel cost method to this new set of visit rate/travel cost data allows estimation of Marshallian constant crowding demand curves for the existing user density and for each of the user densities proposed in the contingent market scenarios.

The combined approach simplifies the multinomial choice contingent valuation method because it does not require survey respondents to consider money values. Whereas in the multinomial approach respondents are required to consider their behaviour at a given price/quality combination in which the price may be different to that currently faced, the combined approach requires respondents to consider their behaviour at hypothesised quality levels at the prices they currently face[19]. Consequently, the combined approach has identical incentives to indulge in strategic behaviour as the quantity-estimating contingent valuation approach and the respondent also has a simpler task because one less parameter is varied.

The costs of this simplification are that the analyst has a much more difficult task than applying contingent valuation directly. As well as the greatly increased data manipulation required by the combined approach (relative to both the contingent valuation and travel cost approaches), the assumptions inherent in any travel cost model (such as choice of functional form, treatment of multiple-purpose trips, and the value of travel time) introduce many potential sources of error into the pure contingent valuation approach. The validity of single-site travel cost models is questioned earlier in this chapter. Those concerns apply equally to the combined approach.

## 6.3 Choice of approach

In a survey of hedonic and travel cost models Mendelsohn and Brown (1983) conclude:

> If the purpose of the analysis is to examine the value of changing a characteristic of a site, the advanced travel costs methods are most useful. If individuals can choose only one site from their residence, the [generalised travel cost] model is best. However, if individuals can choose from a variety of sites, either the hedonic travel cost or [multiple site travel cost] approach is best. The hedonic travel cost is relatively more adept at handling system-wide changes in characteristics and in dealing with a large number of attributes. The [multiple site travel cost] approach, on the other hand is more appropriate when there are a limited number of site types and when the quality of only a single or few sites are to be altered. (Mendelsohn and Brown, 1983: p.618)

[19] Because some people may begin to use a site after improvements in site quality it is necessary to survey non-users, as well as site users, in the contingent market prior to application of the second travel cost model when the zonal travel cost method is used. This is not a problem with reductions in site quality, which lead to use by a sub-set of existing users.

However, the recent work of Smith and Kaoru (1987) indicates that the hedonic travel cost method may not justify the support that Mendelsohn and Brown offer it. The characteristics approach is a potentially useful tool, but it harbours many strong assumptions and remains unvalidated. The multiple site travel cost method remains as the only revealed preference technique which may be appropriate to value endogenous quality changes, however this approach has difficulties in accounting for multiple dimensions of quality, requiring aggregation of site attributes into a single quality index.

The value-estimating form of the contingent valuation approach is not applicable to estimating constant crowding demand curves, but is applicable to identification of optimal capacities under specific rationing mechanisms. Quantity-estimating forms of the contingent valuation method offer a means of estimating Marshallian constant crowding demand curves. These techniques may be susceptible to a variety of biases, but existing evidence shows that these are likely to have minimal effect, and are likely to be less than the biases arising from the value-estimating forms of contingent valuation. Quantity-estimating contingent valuation techniques have not been used to identify constant-crowding demand curves.

The combined travel cost/contingent valuation approach introduces the problems associated with the travel cost method while offering no real advantage over the contingent valuation method.

The value-estimating form of the contingent valuation approach appears to offer the best possibilities for estimating constant crowding demand curves, although the characteristics approach, hedonic travel cost approach, multiple-site travel cost approach, and combined travel cost/contingent valuation approach also offer potential methods. All of these approaches yield estimates of Marshallian demand functions, except for the characteristics approach which, because it estimates parameters of the utility function, can be used to derive Hicksian demand functions.

# CHAPTER SEVEN

# WELFARE THEORY OF QUALITY CHANGES

## 7.1 Introduction

The objective of this chapter is to identify the efficient level of use of a resource when that level of use is controlled by pricing policy. To this point the economic analysis has assumed that data requirements for determining efficient use levels can be met, but this will not always be the case. Utility functions cannot be observed, nor can Hicksian-compensated demand functions in many circumstances. Neither utility functions nor Hicksian-compensated demand functions can be estimated from observed Marshallian demand functions (Bockstael, McConnell and Strand, 1991).

Measures of welfare impacts are exact when they are made with respect to Hicksian-compensated demand functions (in this case the relevant constant crowding demand function). The findings of the previous chapter indicate that, in many circumstances, Hicksian demand information is unavailable. However, it may sometimes be possible to obtain Marshallian demand information when Hicksian information is unavailable. It is well known that if there are no income effects the use of Marshallian data causes no error in the measurement of welfare impacts of price changes. In general, however, utility functions cannot be assumed to take the form necessary to preclude income effects. Willig (1976) has provided a method for estimating the discrepancies introduced into measures of welfare change, contingent upon a price change, when there is no change in quality. In many instances of practical significance the error introduced by use of Marshallian data is small in comparison to measurement errors.

This chapter progresses towards its goal in a series of steps. The first involves identifying the impact of a quality change in Hicksian compensating terms (Section 7.2). In this step the quality change is assumed to be exogenous and price for use of the resource is held constant[1]. Chapter Four showed how total use can be controlled via prices. The next step is to introduce a price change and determine the impact on (compensated) demand. Section 7.3 derives the Hicksian compensating measure of benefit change contingent upon a price-induced quality change. The following step is to identify the change in price necessary to attain any desired quality level (which in this case is signified by the total level of facility use). Section 7.5 addresses the magnitude of errors contingent upon the use of Marshallian data in place of Hicksian compensating data for determining efficient use levels and measuring the welfare impacts of price changes.

## 7.2 Effects of a quality change

Following Just et al. (1982, Appendix B), it is possible to derive an exact measure of the change in an individual's welfare for a quality change, given that prices are constant.

Hicksian compensating variation is the change in income necessary to attain the initial utility level, after a change in quality. Compensating variation (C) may be found by solving the following equality, where P is a vector of prices, K is quality of the congestible good[2], and M is income. The subscripts denote variable

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[1] This line of analysis allows discrepancies from equilibrium. Clearly, price can not be held constant while expected use declines and actual use increases. When quality is an exogenous variable (such as the quality of walking tracks in the wilderness) this problem does not surface. Section 7.3 will address the issue of the price change needed to reattain equilibrium. The concept of exogenous quality is completely artificial, but serves an important heuristic process in linking analysis of congestion with existing analyses of the impacts of changes in quality.

[2] Note that there are minor changes in notation in this chapter. Whereas previously the level of actual resource use (X) was used as the measure of quality, in places in this chapter the concept of quality is somewhat more general and is denoted by the letter K.

levels before (=0) and after (=1) the quality change. V is the individual's indirect utility function.

$$V(P_0,K_1,M_0-C) = V(P_0,K_0,M_0) \qquad 7.1$$

C may be found by solving the dual of the utility maximisation problem. That is, it is possible to identify the minimum expenditure (m) necessary to attain any level of utility (U), given price (P) and quality (K) parameters;

$$m = m(P,K,U) = \sum_{i=1}^{n} p_i\bar{q}_i(P,K,U) \qquad 7.2$$

where the $\bar{q}_i$'s are compensated demands, found by solving the cost minimisation problem[3].

Trivially;

$$M_0 = m(P_0,K_0,U_0) \qquad 7.3$$

Compensating variation for a quality change is then;

$$C = m(P_0,K_1,U_0) - M_0 \qquad 7.4$$

The change in income necessary to compensate for a change in a single price is found by differentiating Condition 7.2 with respect to the changed price;

---

[3] The $\bar{q}_i$'s are the $q_i$,s which solve the following cost minimisation problem:
Minimise P.Q subject to $U(Q,K)=\bar{U}$
where P is a vector of constant prices, Q is a vector of compensated demands, and K is the (scalar) quality of the congestible good. See Appendix A for a worked example.

$$\frac{\partial m}{\partial p_j} = \bar{q_j}\,(P,K,\bar{U}) + \sum_{i=1}^{n} p_i \frac{\partial \bar{q_i}\,(P,K,\bar{U})}{\partial p_j} \qquad 7.5$$

However, the first-order, necessary conditions for utility maximisation subject to a budget constraint (the dual of the cost-minimisation problem) include,

$$\frac{\partial U}{\partial q_i} = \lambda p_i \qquad 7.6$$

where $\lambda$ is the marginal utility of income.

Hence,

$$\sum_{i=1}^{n} p_i \frac{\partial \bar{q_i}}{\partial p_j} = \frac{1}{\lambda} \sum_{i=1}^{n} \frac{\partial U}{\partial q_i} \frac{\partial \bar{q_i}}{\partial p_j} = \frac{1}{\lambda} \frac{d\bar{U}}{dp_j} = 0 \qquad 7.7$$

as long as quality is independent of prices (since $dU = 0$ along an indifference surface). Therefore, the change in income needed to compensate for a change in price is the value of Hicksian compensated demand:

$$\frac{\partial m}{\partial p_j} = \bar{q_j}\,(P,K,U) \qquad 7.8$$

It is now possible to employ the compensated demand functions to evaluate welfare impacts of price changes. Consumer welfare change contingent upon change in prices is;

$$C = -\int_L \sum_{j=1}^{n} \frac{\partial m}{\partial p_j}\, dp_j \qquad 7.9$$

where L is the path of integration (the order in which prices are changed).

For a single price change this is;

$$C = m(P_0,K,\overline{U}) - m(P_1,K,\overline{U}) = -\int_{P_0}^{P_1} \frac{\partial m(P,K,\overline{U})}{\partial p_j}\, dp_j \qquad 7.10$$

$$= -\int_{P_0}^{P_1} \overline{q}_j(P,K,\overline{U})\, dp_j$$

This measure is interpreted graphically as the area to the left of the compensated demand curve, between the price lines.

Similarly, consumer welfare change contingent on a quality change is;

$$C = m(P_0,K_0,\overline{U}) - m(P_0,K_1,\overline{U}) = -\int_{P_0}^{P_1^*} \frac{\partial m(P,K,\overline{U})}{\partial K}\, dp_j \qquad 7.11$$

where $P_0$ is the original price vector, and $P_1^*$ is the "choke price", at which (compensated) demand for good j falls to zero, i.e.;

$$0 = q_j(P_1^*,K,U) \qquad 7.12$$

Alternatively, using the inverse compensated demand function:

$$P_1^* = p_j(0,K,U) \qquad 7.13$$

The welfare measure identified in Equation 7.11 can be represented graphically as the area between two compensated demand curves, above the price line.

Total benefits obtained from resource use include those benefits already identified, which belong to consumers, and those appropriated by resource suppliers (producer benefits). For a resource that is costless to supply, producer benefits (B) are simply equal to compensated revenue .

$$B = p_i.q_i(p_i,K,U) \qquad 7.14$$

The change in producer benefits contingent upon a quality change in good i is;

$$\Delta B = p_i.q_i(p_i,K_1,U) - p_i.q_i(p_i,K_0,U) \qquad 7.15$$

More generally,

$$\frac{dB}{dK} = p_i \frac{\partial q_i}{\partial K} \qquad 7.16$$

Adding the producer and consumer welfare changes contingent on a quality change yields;

$$\begin{aligned} dW &= \frac{\partial}{\partial K}[\int_{p_0}^{p(0,K,\bar{U})} q_i(P,K,\bar{U})]\, dp_i + p_0.\frac{\partial q_i}{\partial K} \\ &= \int_{p_0}^{p(0,K,\bar{U})} \frac{\partial q_i}{\partial K}\, dp_i + \frac{\partial p_i}{\partial K}.q_i(p_i(0,K,\bar{U}),K,\bar{U}) + p_0.\frac{\partial q_i}{\partial k} \qquad 7.17 \\ &= \int_{p_0}^{p(0,K,\bar{U})} \frac{\partial q_i}{\partial K}\, dp_i + p_0.\frac{\partial q_i}{\partial K} \end{aligned}$$

[4] In other words, total benefit, which is the sum of consumer and producer benefits, is the total area under the Hicksian-compensated constant crowding (or constant quality) demand curve.

The second term of the second line in Equation 7.17 disappears because the second part of that term $[q_i(.)]$ is identically zero.

Alternatively, the inverse demand function may be used to measure the total welfare change contingent on a quality change;

$$\begin{aligned} dW &= \frac{\partial}{\partial K}\left[\int_0^{q_i(p_0,K,\bar{U})} p_i(q_i,K,\bar{U})\, dq_i\right] \\ &= \int_0^{q_i(p_0,K_0,\bar{U})} \frac{\partial p_i(q_i,K,\bar{U})}{\partial K}\, dq_i + \frac{\partial q_i(p_0,K,\bar{U})}{\partial K}\cdot p_0 \end{aligned} \qquad 7.18$$

If the Utility function is known, it is possible to measure welfare impacts of quality changes by solving either Equation 7.17 or Equation 7.18.

## 7.3 Effects when quality and price both change

In the situation where a less-congested recreational experience is provided by means of increasing prices to reduce demand for a facility, two parameters are changed concurrently. The increase in price <u>induces</u> a concurrent increase in quality whenever quality is related to user density. A money measure of the welfare impacts of a price-induced quality change may be evaluated by comparing the areas under Hicksian compensated constant crowding demand curves at the initial and final states. The compensating variation for consumers for such a change is;

$$C = M(P_1,K_1,U_0) - M_0 \qquad 7.19$$

Exact measures of benefits accruing to consumers and producers are the areas under Hicksian-compensated constant quality demand curves. Benefits obtained before a quality change are:

$$W_1 = \int_0^{q_1} \phi^H(X^d, K_1)dX^d \tag{7.20}$$

where $\phi^H$ is the Hicksian constant quality demand function,

$X^d$ is the actual level of facility use,

$K_i$ is a measure of quality, and

$q_i$ is Hicksian-compensated demand at quality $K_i$.

Benefits received after a quality change are:

$$W_2 = \int_0^{q_2} \phi^H(X^d, K_2)dX^d \tag{7.21}$$

The change in benefits contingent upon a quality change is therefore:

$$\Delta W = W_2 - W_1 = \int_0^{q_2} \phi^H(X^d, K_2)dX^d - \int_0^{q_1} \phi^H(X^d, K_1)dX^d \tag{7.22}$$

which is an exact way of stating Equation 4.11 in the absence of supply costs[5].

A price-induced change in the actual use level of a congested resource may be considered as a series of steps. These are:

Step 1: Set new quality level (amount of use expected).

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[5] Equation 4.11 is the condition which maximises the sum of consumer and producer benefits, it is:

$$\phi(X^*, X^*) + \int_0^{X^*} \phi_2(X^d, X^*)dX^d - MC(X^*) = 0$$

Step 2: Determine the price that will sustain the new quality level (from the market demand curve).

Step 3: Change the price of resource use to the level identified in Step 2.

Although the change in price causes the change in quality, analysis of consumer welfare impacts is simplified by considering the two welfare-changing steps (Steps 1 and 3) separately. The welfare changes are; the change in area under the demand curve because of a change in quality (holding price constant), and the change in area under the demand curve because of a change in price. The first change is a result of a shift in the demand curve because of the change in quality, while the second is a result of a move along the (new) demand curve because of a change in price.

## 7.4 Errors from use of Marshallian demand functions

If the utility function or the compensated demand functions are known it is possible to evaluate a price-induced quality change directly through Equation 7.19. However, such information is not usually available, but Marshallian constant-crowding demand functions may be available and could be used as approximations to the Hicksian constant-crowding demand functions.

The question of the accuracy of the Marshallian approximation therefore arises. Willig (1976) has shown that, in most practical cases, use of Marshallian demand information to estimate consumer welfare changes contingent upon price changes introduces very little error. The Marshallian approximation error is usually considered to be insignificant when compared to errors in demand estimation. Willig provides methods for estimating Hicksian welfare measures from

Marshallian measures in those cases where the error in approximation is judged to be too great to be ignored.

Change in prices for congestible goods provides more sources of approximation error than the constant quality case addressed by Willig. Firstly, it is well known that there is a path dependency problem with use of Marshallian estimates (Just, Hueth and Schmitz, 1982), evaluating the change along a path which changes quality and then changes price will yield a different estimate of welfare change than if that change were evaluated along a change of price, then change of quality, path. Secondly, as indicated by Bockstael, McConnell and Strand (1991), a change in quality which does not have an associated price change cannot be evaluated as the sum of two Willig-like errors because the price at which the Marshallian and Hicksian-compensated constant quality demand curves for the new quality level intersect ($p_x$) will not be the initial price ($p_1$). Thirdly, price-induced changes in quality compound the foregoing problem by adding an additional source of error.

The second and third additional sources of approximation error are illustrated in Figures 28 to 32, assuming a path which first changes quality, then price. Figure 28 illustrates the quality change step. Point G represents the initial conditions, where $q_0$ units of good i are consumed at price $p_0$. The Marshallian ($X_0^M$) and Hicksian-compensated ($X_0^H$) constant quality demand curves for good i intersect at G, with the Hicksian curve being the steeper of the two. A change (improvement) in quality induces a change in consumption (increase) of good i. Because quality has improved consumers can attain higher indifference curves at their initial incomes, resulting in improved consumer welfare. If consumer incomes are reduced to compensate for this wealth effect, their consumption of good i will reduce (as long as good i is a normal good). The Hicksian, income-compensated, demand curve at the higher quality level ($X_1^H$) therefore intersects the price line ($p_0$) at a lower quantity of good i than does the Marshallian demand curve at the higher quality ($X_1^M$). Because the Hicksian demand curve is steeper than the Marshallian demand curve, the two will intersect at a price for good i ($p_x$) which is greater than the current price ($p_0$). There is, however, no reason to believe that this intersection occurs in the first quadrant.

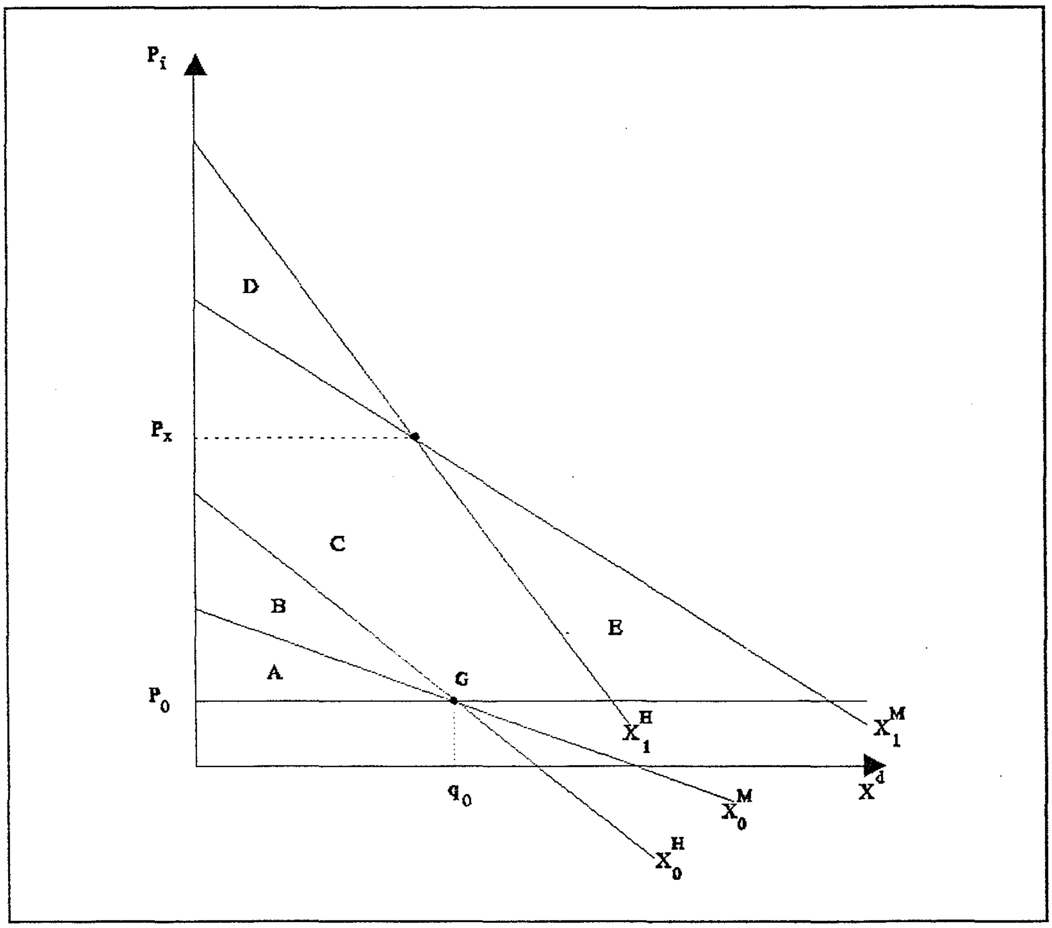


**Figure 28** Welfare impacts of a constant-price quality change.

The true change in consumer welfare[6] of a constant-price quality change is measured by Area (D+C) - the area between the two Hicksian demand curves - in Figure 28. The Marshallian estimate of this change is Area (B+C+E). The error introduced by use of Marshallian data to estimate the welfare change is

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[6] And social welfare if $P_0$ = Marginal cost = average cost.

therefore Area (E+B-D). Willig's method can be used to estimate areas like B, and Area D if $p_x$ is known, but is not applicable to estimating Area E.

When the intersection of the new constant quality demand curves occurs in the fourth quadrant, Area D does not exist and Area E is large. In this case the estimation error from using Marshallian constant quality demand curves is Area (B+E), which is positive, implying that the change in Marshallian surplus is an overestimate of true consumer welfare change. In this case, if Marshallian estimates were used, quality would be set too high for consumptive efficiency and the resource would be underutilised.

Similarly, if the intersection of the new constant quality demand curves occurs at the current price ($p_X = p_0$), Area E does not exist and Area D is large. Use of Marshallian data will lead to overestimation of total welfare change equal to Area (B-D). In this case it is possible that Area D is greater than Area B and consequently change in Marshallian surplus could be an underestimate of welfare change[7]. However, the sign of the error is indeterminate *a priori* whenever the intersection occurs in the first quadrant.

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[7] The demand curves at the new quality level will intersect at the initial price if there is no income effect, or if quality is irrelevant. i.e. Initially, $X^M(p,q,m(p,q,U)) = X^H(p,q,U)$

Letting q change,

$$\frac{\partial X^M}{\partial q} + \frac{\partial X^M}{\partial m}.\frac{\partial m}{\partial q} = \frac{\partial X^H}{\partial q}$$

Rearranging,

$$\frac{\partial X^H}{\partial q} - \frac{\partial X^M}{\partial q} = \frac{\partial X^M}{\partial m}.\frac{\partial m}{\partial q} = 0 \text{ iff}$$

(i) $\frac{\partial X^M}{\partial m} = 0$ (no income effect) or,

(ii) $\frac{\partial m}{\partial q} = 0$ (quality is irrelevant)

Otherwise, for normal goods,

$$\frac{\partial X^M}{\partial q} > \frac{\partial X^H}{\partial q}$$

Figures 29 to 32 illustrate the third error source, the price change step. The price ($p_1$) needed to sustain the new quality level (Step 3) is identified from the market demand curve, so is invariant to whether Hicksian or Marshallian constant crowding demand curves are used for evaluating welfare changes. Four cases are possible:

**CASE 1**, the new price is greater than the price at which the Hicksian and Marshallian demand curves intersect at the new quality level, $p_1 > p_x$;

**CASE 2**, the new price is less than the intersection price and the intersection occurs in the first quadrant, $p_1 < p_x$;

**CASE 3**, the new price is less than the intersection price and the intersection occurs in the fourth quadrant, $p_1 < p_x$;

**CASE 4**, the new price is equal to the intersection price, $p_1 = p_x$.

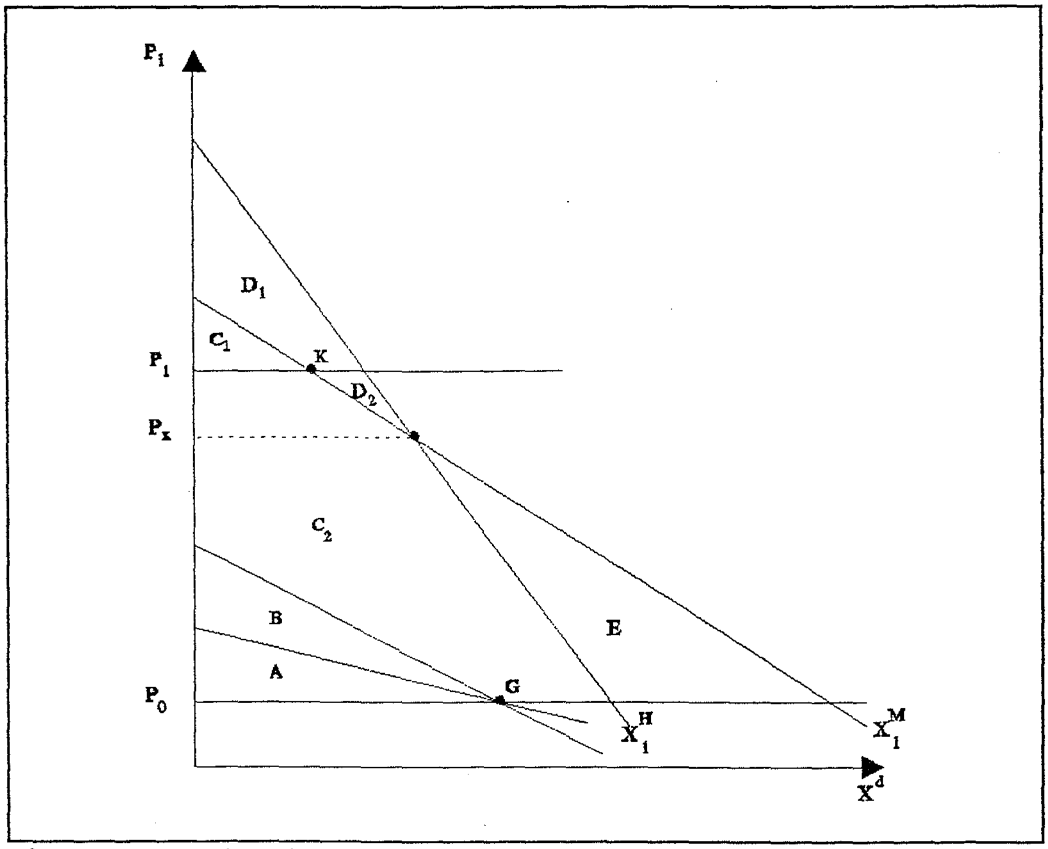


**Figure 29** The price which sustains the quality change is greater than the price at which the demand curves intersect.

The price change step of Case 1 is illustrated in Figure 29. After the quality change, the increase in price from $p_0$ to $p_1$ results in a decrease in consumer benefits of Area ($A+B+C_2+D_2$), equal to the change in area beneath the relevant Hicksian-compensated constant quality demand curve. The Marshallian estimate of this loss is Area ($A+B+C_2+E$). When the price and quantity changes are combined it is seen that the Marshallian estimates of consumer welfare change overstate true change in consumer welfare by Area ($B-D_1$), which is of unknown sign *a priori*.

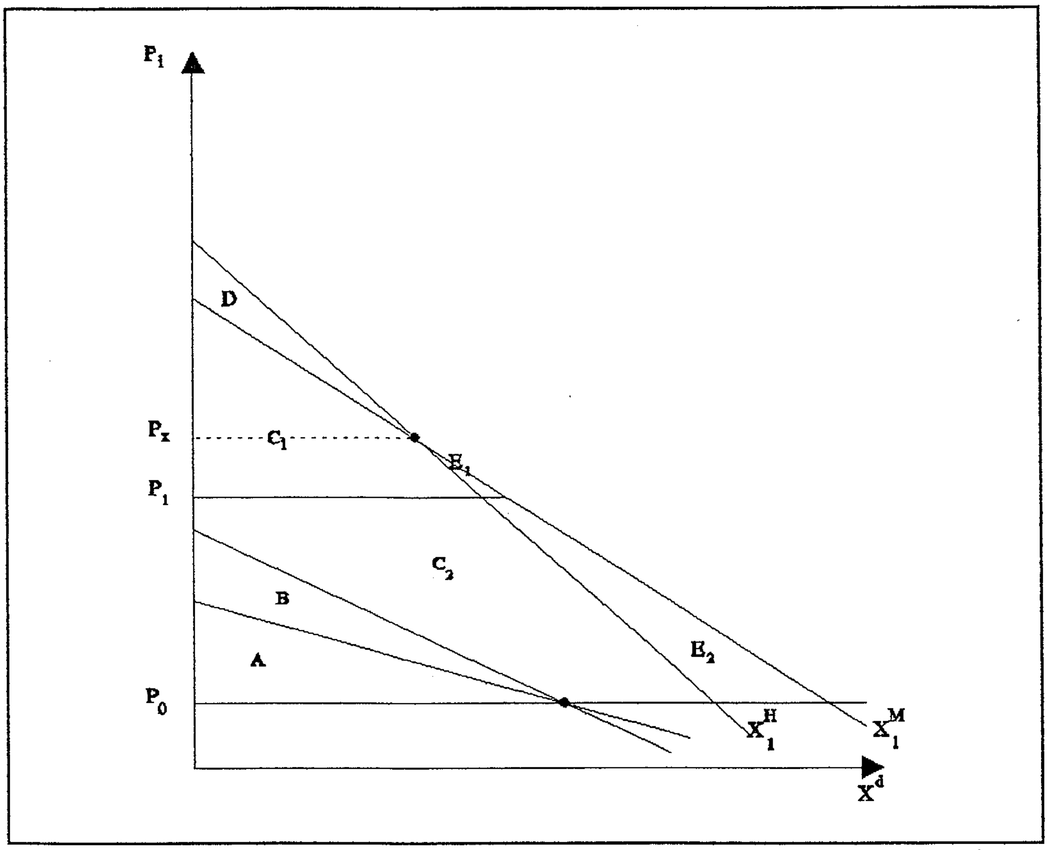


**Figure 30** The price which sustains the quality change is less than the price at which the demand curves intersect.

For case 2, illustrated in Figure 30, the post quality change increase in price from $p_0$ to $p_1$ results in a decrease in consumer benefits of Area ($A+B+C_2$). The Marshallian estimate of this loss is Area ($A+B+C_2+E_2$). When the price and quantity changes are combined, it is seen that Marshallian estimates overstate consumer welfare change by Area ($B+E_1-D$), which is of indeterminate sign.

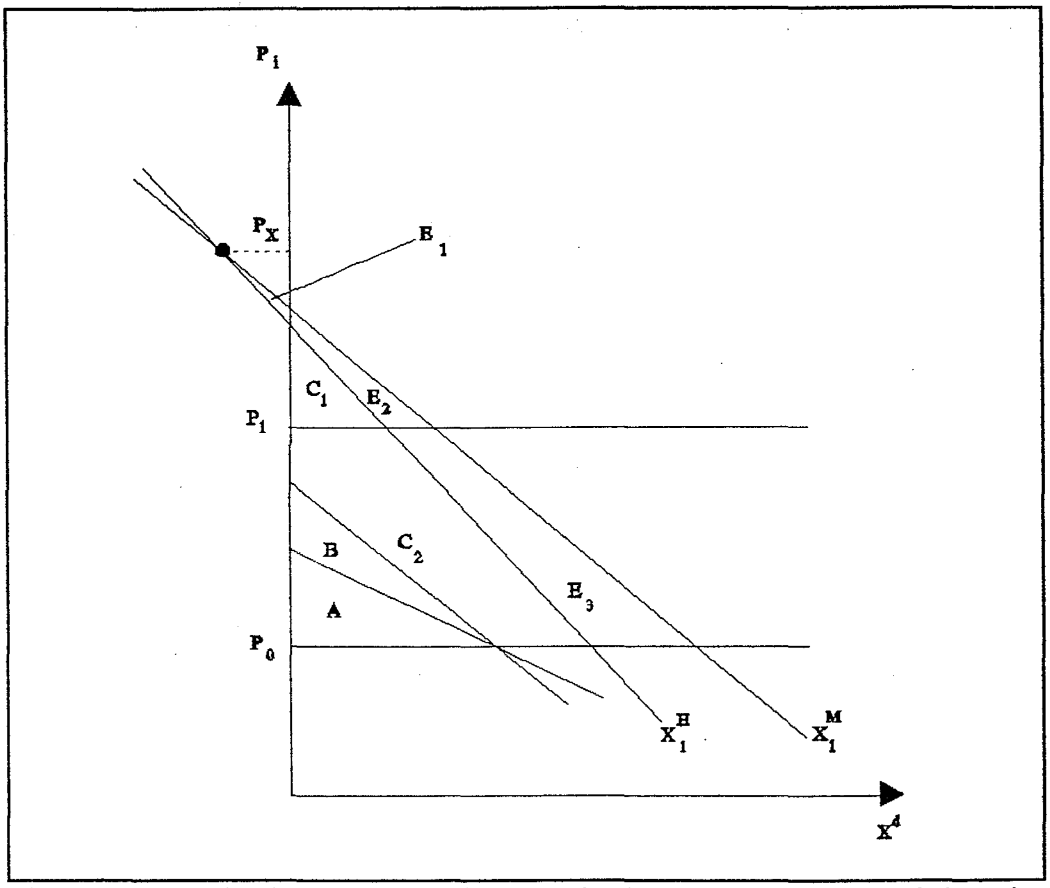


**Figure 31** The demand curves intersect in the fourth quadrant and the price which sustains the quality change is less than the price at which the demand curves intersect.

Figure 31 illustrates case 3, in which the post quality change increase in price results in a decrease in consumer benefits of Area $(A+B+C_2)$. The Marshallian estimate of this loss is Area $(A+B+C_2+E_3)$. Combining the price and quantity changes, it is seen that Marshallian estimates overstate total consumer welfare change by Area $(E_2+B)$, which is unambiguously positive.

Figure 32 illustrates Case 4, the increase in price results in a decrease in consumer benefits of Area $(A+B+C_2)$. The Marshallian estimate of this loss is Area $(A+B+C_2+E)$. Marshallian estimates of total consumer welfare change caused by the price and quality changes are overstatements by Area (B-D), which is of indeterminate sign.

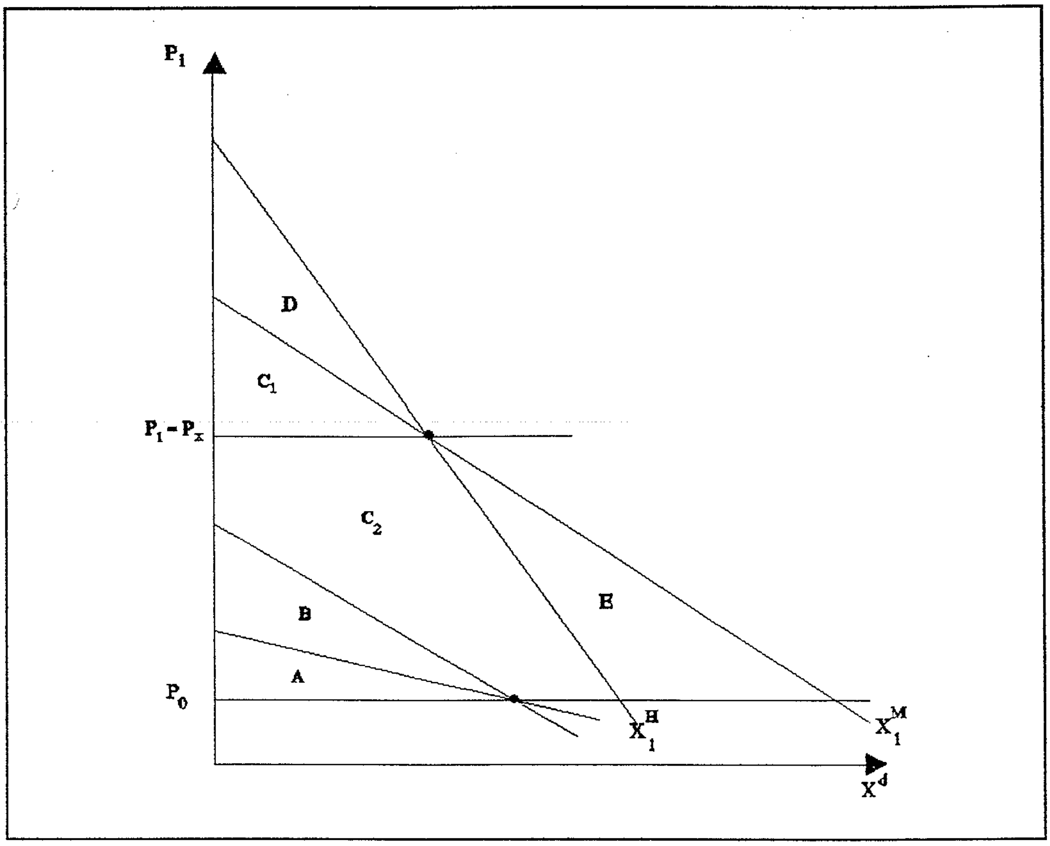


Figure 32 The price which sustains the quality change is equal to the price at which the demand curves intersect.

It is possible to put an unambiguous sign on the errors introduced by using Marshallian demand functions in place of Hicksian-compensated demand functions to evaluate consumer welfare changes contingent upon price changes for non-congestible goods. However, the same is not true for congestible goods. The sign of the error is only known if the utility function or both types of demand function are known. In either of these cases the Hicksian demand functions may be used directly. If the two types of demand curves for the new quality level intersect at the initial price, there is no error in using Marshallian demand information. This condition only occurs if there is no income effect, implying that the Hicksian and Marshallian demand curves are identical, or if quality is irrelevant, in which case a change in price does not influence gross user benefits.

If the Marshallian and Hicksian demand curves at the new quality level intersect in the fourth quadrant (CASE 3), the Marshallian measure of consumer welfare change of a reduction in capacity is an unambiguous over-estimate. Use of Marshallian data in this case would result in setting a level of quality which is too high (too little use) for consumptive efficiency. In all other cases, the errors introduced to estimates of consumer welfare change by use of Marshallian data are of indeterminate sign.

The error in estimated consumer benefit change may be estimated as the difference between two Willig-like areas in the case where the intersection of the Hicksian and Marshallian demand curves at the new quality level occurs at the price which sustains the new quality level ($p_1 = p_X$). Knowledge of whether $p_X$ and $p_1$ coincide and, if so, what their value is may therefore allow use of Marshallian demand data alongside Willig correction factors to identify the consumptively efficient price for a congestible good.

However, in general, $p_1$ is not equal to $p_X$[8]. To see this, consider Figure 29. Points G and K are two points on the market demand curve. Utility varies along the market demand curve, therefore Points G and K will only provide the same utility coincidentally. However, every point on the Hicksian-compensated constant crowding demand curve at the new quality level ($X_1^H$) has identical utility to Point G. If Point G has different utility to Point K, then $X_1^H$ cannot pass through Point K. The only cases in which $p_1 = p_X$ are when utility does not change along the market demand curve, or when Points G and K "straddle" the social welfare maximising point on the market demand curve, identified in Chapter 4. In other words, $P_0 < P^* < P_1$ or $P_0 > P^* > P_1$ is a necessary, but not sufficient, condition for $p_1 = p_X$.

8 An example of a case in which $P_1$ is not equal to $P_X$ is presented in Appendix A.

### 7.4.1 Slutsky identity for quality changes

Let $h_j(P^*,k^*,U^*)$ = the amount of good j consumed to obtain utility $U^*$, at prices $P^*$, and quality $k^*$.

$y^*(P^*,k^*,U^*)$ = the minimum income needed to reach utility $U^*$, at prices $P^*$, and quality $k^*$.

$x_j(P^*,k^*,y^*)$ = the amount of good j consumed with income $y^*$, at prices $P^*$, and quality $k^*$.

Then, by definition:

$$h_j(P^*,k^*,U^*) = x_j(P^*,k^*,y^*(P^*,k^*,U^*)) \quad 7.23$$

Consequently,

$$\frac{\partial h_j}{\partial p_i} = \frac{\partial x_j}{\partial p_i} + \frac{\partial x_j}{\partial y}.\frac{\partial y}{\partial p_i} \quad 7.24$$

which is the Slutsky identity. It is the same as for the case in which quality is not a parameter. Further,

$$\frac{\partial h_j}{\partial k_i} = \frac{\partial x_j}{\partial k_i} + \frac{\partial x_j}{\partial y}.\frac{\partial y}{\partial k_i} \quad 7.25$$

is an identity similar to the Slutsky identity, but having meaning only when quality is a determinant of utility.

### 7.4.2 Finding the intersection of the new demand curves

It was illustrated earlier that when quality improves, the Hicksian and Marshallian demand curves at the new quality level intersect at some price ($p_x$) greater than the price before the quality change ($p_0$). In order to identify $p_X$, totally differentiate the Marshallian and Hicksian constant quality demand functions:

$$dx_i = \left[\frac{\partial x_i}{\partial p_i} + \frac{\partial x_i}{\partial y}.\frac{\partial y}{\partial p_i}\right] dp_i + \left[\frac{\partial x_i}{\partial k_i} + \frac{\partial x_i}{\partial y}.\frac{\partial y}{\partial k_i}\right] dk_i + \frac{\partial x_i}{\partial y}.\,dy \qquad 7.26$$

$$dh_i = \frac{\partial h_i}{\partial p_i}.\,dp_i + \frac{\partial h_i}{\partial k_i}.\,dk_i + \frac{\partial h_i}{\partial U}.dU \qquad 7.27$$

At $p_X$, $dh_i = dx_i$. Letting: $dh_i = dx_i$, $dU = 0$ on the Hicksian demand curve, $dy = 0$ on the Marshallian demand curve, and rearranging terms yields:

$$dp_i\left[\frac{\partial x_i}{\partial p_i} + \frac{\partial x_i}{\partial y}.\frac{\partial y}{\partial p_i} - \frac{\partial h_i}{\partial p_i}\right] = -\,dk_i\left[\frac{\partial x_i}{\partial k_i} + \frac{\partial x_i}{\partial y}.\frac{\partial y}{\partial k_i} - \frac{\partial h_i}{\partial k_i}\right] \qquad 7.28$$

It is known from the Slutsky identity that the bracketed terms on each side of Equation 7.28 equal zero, so it is not possible to identify $dp_i$ as a function of $dk_i$ using this approach. Consequently, the point of intersection of the Hicksian and Marshallian demand curves for the new quality level cannot be identified.

While it may not be possible to identify $p_X$ exactly without information on the particular form of the utility function or constant quality demand functions, it is possible to identify whether $p_X$ is greater or less than $p_1$. If utility at $p_1$ is less than at $p_0$, consumers will need to be compensated for the price increase with increased income, to enable them to attain their initial welfare level. Such compensatory income would increase demand for the congestible good (assuming it is a normal good), indicating that Hicksian-compensated demand is greater than Marshallian demand at $p_1$. Since Hicksian demand curves are steeper than their Marshallian equivalents, the two demand curves must intersect at some price below $p_1$. In other words $p_X < p_1$. Similarly, if utility at $p_1$ is greater than at $p_0$ then $p_1 < p_X$, by the same reasoning.

## 7.5 When may Marshallian data be used without error?

There are no universally applicable rules which determine the relationships between the true (Hicksian) change in consumer welfare ($\Delta U$) and the Marshallian-based estimates of those changes ($\Delta \hat{U}$), i.e.

$$\begin{array}{lcl} \Delta U > 0 & \not\Rightarrow & \Delta \hat{U} > 0 \\ \Delta U < 0 & \not\Rightarrow & \Delta \hat{U} < 0 \\ \Delta \hat{U} > 0 & \not\Rightarrow & \Delta U > 0 \\ \Delta \hat{U} < 0 & \not\Rightarrow & \Delta U < 0 \end{array}$$

Consider, for example, the first of these conditions:

$\Delta U > 0 \Rightarrow p_1 > p_X$, implying that Case 1, illustrated in Figure 29, must apply. In that case;

$\Delta \hat{U}$ = Area $(C_1\text{-}A)$

$\therefore \quad \Delta \hat{U} > 0 \quad$ iff $\quad$ Area $(C_1\text{-}A) > 0$

By definition, $\Delta U$ = Area $(C_1+D_1\text{-}A\text{-}B) > 0$, but this is not sufficient information to place a sign on Area $(C_1\text{-}A)$. $\Delta \hat{U}$ could be positive, negative, or zero when $\Delta U>0$ (or, for that matter, when $\Delta U<0$ or $\Delta U=0$). Consequently, the conclusion follows that $\Delta U > 0 \not\Rightarrow \Delta\hat{U} > 0$.

These findings lead to the conclusion that knowledge of Marshallian demand functions does not allow evaluation of the sign of welfare impacts of a price change for congestible goods. The question remains as to whether Marshallian constant crowding demand functions can be used to identify the socially efficient price and/or use level.

Total benefits (W) equal the area under the Hicksian-compensated constant crowding demand curve for the current level of use[9].

$$W = \int_0^X \phi^H(X^d,X)dX^d \qquad 7.29$$

The socially efficient outcome occurs when Condition 7.30 is satisfied.

$$\begin{aligned}\frac{\delta W}{\delta X} &= \frac{\delta}{\delta X}\left(\int_0^{X^*} \phi^H(X^d,X^*)dX^d\right)\\ &= \phi^H(X^*,X^*) + \int_0^{X^*} \phi_2^H(X^d,X^*)dX^d \qquad 7.30\\ &= 0\end{aligned}$$

[9] Note that the demand curve in Equation 7.29 is a constant crowding demand curve, and not a constant quality demand curve. Consequently the variable X, representing the level of use, replaces the variable K, which represented quality in earlier demand functions

The Marshallian counterpart to this condition is:

$$\frac{\delta \hat{W}}{\delta X} = \frac{\delta}{\delta X}\left(\int_0^{X^*} \phi^M(X^d,X^*)dX^d\right)$$

$$= \phi^M(X^*,X^*) + \int_0^{X^*} \phi_2^M(X^d,X^*)dX^d \qquad 7.31$$

$$= 0$$

For the Marshallian demand curves to identify the socially efficient use level, $X^*$ must satisfy Conditions 7.30 and 7.31 simultaneously. Since $\phi^H(X^*,X^*) = \phi^M(X^*,X^*)$, the necessary condition is:

$$\int_0^{X^*} \phi_2^H(X^d,X^*)\, dX^d = \int_0^{X^*} \phi_2^M(X^d,X^*)\, dX^d \qquad 7.32$$

where $X^*$ satisfies Condition 7.30. Clearly, Condition 7.32 will not be universally satisfied, implying that Marshallian demand functions cannot be relied upon to identify the socially efficient use level[10].

## 7.6 Summary and conclusions

This chapter has analysed the implications of using Marshallian demand information to make allocation decisions for congestible goods. It initially developed the theory of welfare change for an autonomous quality change, then

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[10] There are some special cases which satisfy Condition 7.32. These include those cases in which (i) Marshallian and Hicksian-compensated constant crowding demand curves have identical derivatives with respect to actual use for all levels of expected use, and
(ii) Marshallian and Hicksian-compensated constant crowding demand curves are both quasi-linear (demand curves for different expected use levels are identically shaped, but are vertically shifted) and their derivatives with respect to actual use are identical (at any level of actual use) for the socially efficient level of expected use.

These special cases cannot, however, be identified without knowledge of the Hicksian-compensated constant crowding demand functions. If this knowledge were available the Hicksian functions could be used directly to identify the socially efficient use level.

extended that analysis to situations in which quality is autonomous. Conditions for optimality and the measurement of welfare changes were developed using both Marshallian and Hicksian demand information. Those conditions were then compared to determine whether it is necessary to use Hicksian demand information to obtain social efficiency, and whether there are any consistent biases in use of Marshallian data - as there are in the simple case of a price change with quality exogenous.

The findings of this chapter are that knowledge of Marshallian constant crowding demand functions does not allow identification of the sign of consumer welfare change contingent upon price changes, and does not allow identification of the socially efficient level of use, for congestible facilities.

These findings have serious implications for managers of congestible resources. Managers who wish to maximise revenue or profits from a congestible resource have only to be concerned with the Marshallian market demand function, which is relatively easy to identify. Managers concerned with maximising social or consumer welfare require information on either the utility function(s) which underlie demand, or with the Hicksian-compensated constant quality demand functions themselves. Efficient congestible resource allocation is therefore reliant on the ability to apply non-market valuation techniques to congestible resources, the difficulties of which were identified in Chapter 6. Consequently, a serious problem exists for those who wish to manager congestible resources to maximise social welfare. In effect, even when there is agreement on social values (i.e. a decision has been made to manage to maximise social welfare) because the "scientific facts" (location of compensated demand curves in this case) are unknown, decisionmaking is currently unable to escape from the judgemental realm identified in Figure 6.

# CHAPTER EIGHT

# CONCLUSIONS

This thesis was motivated by the concern that congestible resources are possibly not being managed in ways that are compatible with some common management objectives. The usual, tragedy of the commons, justification of the need for management of congestible goods is provided in the introduction to this thesis. It takes the line that individuals acting in their own best interests undertake actions which cause reductions in others' welfare. The consequence is that social welfare, measured using the potential Pareto improvement criterion, is less than it would be if people's actions were constrained in some optimal way.

Following chapters reviewed current methods for identifying the levels that constraints to backcountry recreation resource use should be set at, and identified problems with those methods. Economic analysis was developed to identify efficient resource allocations, to explain observed behaviours, and to understand the impacts of some management parameters. Non-efficiency objectives were introduced, and the efficiency and revenue costs of pursuing an equal opportunity objective were analysed. Finally, the ability to measure demand for congestible backcountry recreation facilities was analysed and the efficiency costs of using an approximation to the true welfare change were investigated.

Section 8.1 summarises the main findings of this study and the contribution they make to current understanding of congestion management. Policy implications arising from this analysis are presented in Section 8.2, research limitations and the implications for future research are discussed in Sections 8.3 and 8.4 respectively.

## 8.1 Main findings

Several weaknesses in existing models of backcountry recreation were identified. These models were able to be extended to include objectives for management and demand for use of recreational resources. The revised model shows the limits of existing economic analyses, and indicates potential areas for future research.

Economic models were developed to investigate the positive and normative aspects of managing congestible resources. These models built upon existing forms of analysis to analyse aspects of congestible resource management. They are reduced form models of some of the aspects incorporated in the revised model of backcountry recreation developed in Chapter Three, and so are not capable of being used to determine "optimal" resource allocations, except in some extremely simple special cases. The economic analysis does, however, provide some general principles which are likely to provide guidance to managers of congestible resources. The principles to emerge are:

1) A profit maximising monopolist would not in general allow an efficient level of access to congestible resources. Consequently, privatisation of unique backcountry recreation resources or leaving their management "to the market" would be inefficient. This argument provides a *prima facie* case for some form of social management but, without knowledge of the relative transaction costs and the potential for government failure, cannot be taken as a complete justification for such management.

2) Where several types of congestible use may be made of a single resource, too much use of each type occurs (given the level of the other activities) under open-access conditions. If one use is limited, the other use(s) will occur at super-efficient levels, implying that all uses must be managed to attain efficiency (again within limitations imposed by transaction costs).

3) Displacement is the result of unconstrained use and may result in satisfied users, but can concurrently result in a reduction in aggregate use benefits. "Satisfaction" on its own is not a suitable management goal when there are efficiency and/or distributional objectives. Efficient management requires knowledge of crowding-dependent demand functions for all users, existing and potential, to determine how much use of the resource each potential user should be permitted to make. Distributional concerns require definition of <u>who</u> should be satisfied.

4) The process of rationalisation implies there may be no observed change in expressed satisfaction with an increase in user density, but this observation should not be taken to imply that increases in user density are efficient. The nature of the experience may have changed, possibly resulting in diminished individual (and aggregate) user benefits. Once again it is apparent that efficient resource management requires knowledge of crowding-dependent demand functions for all users, existing and potential, so that the efficient combination of user type(s) and use levels may be identified.

5) When choosing between price rationing, lottery rationing and no rationing of a congestible resource, an open-access use policy will often (but not always) maximise the benefits <u>obtained by resource users</u>, but will never maximise total (consumer plus producer) benefits. In the absence of transaction costs, open-access

use is not compatible with efficient management of congestible resources. However, if the management objective is to "maximise the benefits obtained by resource users" then open-access will often be the optimal policy.

6) The efficient capacity for a congestible resource is dependent upon the method that will be employed to ration use. There is no single efficient carrying capacity for a congestible resource. Consequently, it is not possible to meet efficiency and distributional goals by determining the efficient amount of use and then allocating that use according to some independently determined distributive criteria. It is, however, possible to ensure efficiency given the allocation method. For example, the lottery may be chosen as the preferred allocation method because it ensures equality of opportunity, the objective of resource allocation in this case being to maximise total benefits subject to the constraint of equal opportunity. Satisfaction of the objective could be attained by identifying the efficient carrying capacity under lottery rationing.

7) There are no universal rules relating the magnitudes of benefit measures under pure price, pure lottery and open-access allocation schemes. It is only possible to derive these once the form of the crowding-dependent demand functions, transaction costs, and attitudes to risk are known.

(i) In the absence of transaction costs, with consumer risk-neutrality or risk-seeking, consumers will prefer an efficient lottery to efficient pricing. This occurs because the efficiency gains from pricing will not flow to the resource users unless they are also the resource owners, but efficiency gains from lottery rationing are all captured by consumers. This result is not generalisable to risk-averse resource users, their preferred outcome being dependent upon the degree of risk aversion, the chances of success in the lottery, and the benefits obtained from use under the two allocation schemes.

(ii) Current, risk-neutral and risk-seeking consumers will prefer an efficient lottery to open-access.

If management objectives require the maximisation of expected user benefits (rather than total benefits) then, in the absence of transaction cost differences, lottery rationing is preferable to both price rationing and open-access.

8) Chapter Five analysed the implications of mixing price and lottery rationing mechanisms. The trade-offs in outcomes (efficiency, aggregate expected consumer benefits, expected producer benefits, and per-capita expected consumer benefits) were illustrated for the specific case of a linear functional form. While not all of the findings are generalisable, some general rules emerged.

The mixed mechanisms were found to intermediate between pure price and pure lottery rationing on expected efficiency, expected aggregate consumer benefits, and expected revenue criteria. Pricing performed best on efficiency and revenue criteria, while lottery rationing performed best on the expected consumer benefit criterion.

These rules imply that there is no single, dominant allocation method. Choice of an appropriate allocation method depends upon the elements of the objective function and the weightings they are given.

9) Chapter Six reviewed existing methods of estimating demand for congestible recreation resources. No method was found to be without some form of problem, but the most promising methods (in terms of theoretical consistency and practical applicability) appear to be the quantity-estimating forms of the contingent valuation

approach. Only one potentially usable method (the characteristics approach) provides the theoretically correct Hicksian measures of welfare change. The others all provide Marshallian approximations to Hicksian demand curves.

These findings have serious implications for demand information based management of congestible resources if Marshallian approximations to congestible demands are unable to provide useful approximations to welfare changes. They suggest that the basic information on which economic decisions are based is currently unobtainable, effectively ruling out the use of economic approaches to decision making.

10) Chapter Seven investigated the errors introduced by the use of Marshallian demand information to manage congestible resources. It was found that Marshallian demand functions cannot be relied upon to identify the socially efficient resource use level or price. Further, Marshallian demand information is not even able to indicate the true sign of the welfare change contingent upon a price change for a congestible good. The conclusion to follow from this finding is that, until new approaches to measuring Hicksian demands for congestible goods are developed, or the characteristics approach is further developed, it is not possible to apply the economic theory developed here to understand the welfare changes contingent upon changes in management of congestible resources.

11) Appendix A found that, even for the most basic case of a two good world, utility functions able to satisfy some simple, widely-accepted axioms are unable to take simple functional forms. The corresponding Marshallian and Hicksian demand functions are consequently not in easily estimable forms. One of the most simple functional forms satisfying the axioms was used to illustrate this and to confirm the welfare theoretic problems associated with using Marshallian demand information

in place of Hicksian demand information. It follows that attempts to estimate demand and utility functions for congestible goods using the commonly applied, simple functional forms are likely to be theoretically inconsistent.

While these principles are not all completely new, they all add to the existing body of knowledge regarding the management or theory of congestible resources. For example, Principle 1 is already widely known, however the analysis of Chapter Four corrects a fault in an earlier analysis. Principles 3 and 4 are also already known, but the analysis of Chapter Four models them from a new perspective and clarifies the economic reasoning behind the displacement and rationalisation phenomena. Principle 2 and Principles 5 through 11 are all extensions or additions to existing knowledge.

## 8.2 Implications for the management of congestible backcountry recreation resources

The principles of the preceding section suggest that, at present, economics can play only a limited role in the management of congestible recreation resources. Principles 1 through 4 justify the need for management, and identify the need for congestion-dependent demand information to allow efficient management. Principles 5 through 8 introduce the possibility of management objectives other than efficiency and illustrate some of the implications of adoption of those criteria. Here again it was found that whenever revenue or efficiency enter the objective function congestion-dependent demand information is necessary to determine the optimal management strategy.

The theory of efficient congestible resource management is well developed, and has been extended here to allow consideration of some other management objectives. However, Principles 9 through 11 indicate that this theory cannot be implemented at present. There are currently no theoretically acceptable methods for measuring demand for congestible non-market goods, methods which provide approximations have errors of unknown direction and magnitude, and theoretically acceptable functional forms take much more complex structures than the forms commonly estimated in non-market valuation studies.

The preceding analysis does not bode well for the input of economic advice for the management of congestible backcountry recreation resources. Chapters Four and Five illustrate the possibility of developing economic models once decision criteria are known. If appropriate demand information were available, demand-based models could be developed to illustrate the positive consequences of employing different resource allocation methods and parameters, allowing the normative evaluation of alternative policies. The models developed in this thesis do not specify all of the links described in the model developed in Chapter Three. However, there appears to be no reason why those models could not be adapted to include the additional linkages. Whether this is worthwhile depends upon the ability to apply the knowledge that is presently available.

Problems arise in the practical implementation of the existing economic models. Implementation requires knowledge of demands for extra-market congestible resources. While non-market valuation is a rapidly developing area of economic research which has discovered procedures for valuing many things, it has not specifically addressed the development of methods suitable for providing the information needed for management of congestible resources. The review of non-market valuation methods conducted in Chapter Six concluded that there is currently no practical way of identifying Hicksian-compensated demand curves for congestible goods. The best that can be done is to estimate the related Marshallian demand curves.

For non-congestible goods Marshallian demand curves provide close estimates of Hicksian-compensated demand curves, and the biases in measures of benefit introduced by use of Marshallian measures are of known sign, are usually small, and may be closely approximated. The same does not hold for congestible goods. It is not possible to use the approximation techniques for normal goods to identify whether errors are large or small, or even to place a sign on them. Consequently, it is not possible to identify whether specified changes in price or permitted use levels result in an increase or decrease in aggregate social welfare.

## 8.3 Limitations of the analysis

Theoretical studies which attempt to apply or extend economic analysis to relatively new topic areas typically make vast simplifications to ease the analytical burden. The cost of these simplifications is that the analysis may not be able to predict real world outcomes well, or approaches derived may not be practically applicable. This study is no different from most others in that it has made some rather heroic simplifications. It is important to identify explicitly what those simplifications are in order that the findings are treated with an appropriate degree of caution and to indicate where progress may be made in ensuing studies.

A major limitation of this study is the assumption of a fixed-size facility. Clearly, an important concern for management is determination of the quantity of resource to allocate to congestible uses relative to other uses. The theory for making this allocation decision on efficiency grounds is relatively straightforward. In fact, the shadow price for resources allocated to congestible uses was derived in

Section 4.6. This shadow price could be compared to the value of resources in alternative uses to determine which is oversupplied. Alternatively, a more general model, incorporating congestible and non-congestible resources could be developed. However, until Hicksian demand information for congestible resource uses is available application of such models remains problematical.

Much of the analysis conducted in this thesis was aimed at developing the underlying economic concepts for management of congestible resources and did not attempt to carry this analysis through to a level suitable for practical implementation. The main areas neglected because of this approach include: transaction costs, the role of risk, and costs external to users.

Transaction costs are likely to vary on a case by case basis, both in their magnitude and distribution, allowing them to be treated only in the most general way in this theoretical analysis. However, transaction costs are important determinants of efficiency, profitability and equity so need to be considered in any applied analysis of alternative resource allocation scenarios. It is relatively common to see "management costs" addressed in this manner, and that is appropriate if enterprise efficiency or profitability are the only objectives of concern. If a more general definition of efficiency is adopted, or equity concerns are important, then transaction costs falling on resource users should also be included in analysis. Care must then be taken to identify whether estimated demand functions are net of transaction costs or not, which will depend upon the estimation method employed.

Pure price allocation means that everyone who wants to use a resource at the known price can obtain access to it by paying that price. However, risk is an inherent element in many allocation systems. For example, with lottery allocation some potential users will be disappointed because the probability of success is less than unity, but their identity is not known until after the lottery takes place. With physical queues the length of time potential users must queue is not necessarily known before joining the queue. Even if demand is known with certainty, the benefits obtained under lottery and physical queue allocations cannot be. Consequently, in order to compare benefit measures some adjustment for risk must occur whenever people are not risk-neutral. This thesis simplified the problem by assuming risk-neutrality throughout. Real-life applications need to consider how benefit measures should be adjusted to account for the attitudes to risk of the various actors involved.

The economic analysis conducted in this thesis assumed that the only externality imposed by resource use is congestion costs on other resource users. Other externalities may also exist. Examples of these for backcountry recreation include external benefits, such as mental and physical health benefits, and management costs, which have largely been ignored in this study.

The analysis here did not explicitly deal with the equity objective, because it could not be defined. Consequently, it was not possible to investigate combinations of allocation methods and their parameters which optimise some chosen objective function. The initial approach adopted to deal with equity was extremely narrow in that it treated one allocation method (lottery) as a constraint put in place to address equity concerns. Later analysis reviewed the impacts of mixed price and lottery allocation mechanisms, this approach is able to provide positive outputs useful to decisionmakers, but is unable to reach normative conclusions. The investigation undertaken represents a start in understanding the role of allocation mechanisms in the magnitude and distribution of benefits from use of congestible resources, but clearly would benefit from expansion to address the many other allocation mechanisms available.

The economic analyses of Chapter Four contain some elements which may limit practical applicability of the findings. The characteristics approach was developed in graphical rather than mathematical terms, restricting analysis to two characteristics. The graphical approach is useful heuristically, but is limited in analytical ability. Of prime importance is its inability to analyse the effects of increased use on the slopes of resource characteristic rays. Consequently, analysis by the characteristics approach was descriptive and was not developed to a prescriptive level, even for the single (efficiency) objective case. Mathematical modelling of the characteristics approach is one way to achieve prescriptive results for management of congestible resources, the other is further development of the usual "goods approach". The latter course of action was adopted here.

Clearly, impacts of resource use can be both intra and inter-temporal, but this study has focused on intra-temporal effects. The analysis of inter-temporal effects was restricted to the dynamics of reaching equilibrium, it did not investigate the role of the physical impacts of resource users in one period affecting the benefits obtained by resource users in other periods. Such impacts are likely to occur in backcountry recreation because of longlasting user-density dependent impacts such as: trampling of vegetation, littering, and displacement of wildlife.

Much of the economic modelling was restricted to analysis of resources subject to a single, congestible use. Backcountry recreation resources are typically subject to several types of use and within each use there may be many types of user, from solitude seeking to crowd seeking. The implications of management actions in such settings are not inherently more difficult to model than the simple cases analysed so far. Such analysis could be conducted along the lines of the general approach of Section 4.6. The modelling exercise does not present any special difficulties, but as the number of arguments in the objective function increases so does the number of arguments in the demand functions necessary to run the model. The more arguments in the demand functions, the more difficult they are to estimate. Consequently, practical application to such situations is even further distant than for the simple single use cases.

## 8.4 Implications for research

The inability to apply the economic models developed so far suggests that it is fruitless, at this stage, to further develop the economic models to account for all of the interactions specified in the model of backcountry recreation developed in Chapter Three. Such research may satisfy intellectual challenges, but would be of little use in the management of congestible resources.

Further application of economics to the management of congestible backcountry recreation resources relies on the development of methods for identifying Hicksian-compensated demand functions for those resources. Many of the non-market demand revelation techniques analysed in Chapter Six are suitable only for identifying Marshallian demand functions. Consequently, the search should be focused on discovering new methods of non-market valuation, or on development of the characteristics approach pioneered by Greig and Morey.

Appendix A indicates that the Cobb-Douglas utility function is not compatible with commonly accepted axioms which apply in the presence of congestible goods. A starting point for future research may therefore be to identify estimable forms of utility functions which are consistent with the axioms. The parameters associated with these functions could be estimated from observations of recreational facility choice behaviours. In order to validate such a model it would be necessary to observe its predictive ability under alternative conditions, such as when prices, or quality conditions (including crowding) change. This approach would be extremely useful because when utility functions are known it is possible to derive both Marshallian and Hicksian-compensated demand functions. With knowledge of these it is possible to measure the direction and magnitudes of biases introduced by use of Marshallian demand curves to provide information on efficiency of resource allocation options. It may be true that there are no significant differences between the allocations indicated by the two types of demand function.

If the characteristics approach is to be advanced it is important to obtain an improved understanding of the budget allocation process and which activities fall into more or less homogeneous groups competing for budget allocations. A starting point for this field of research (and an indication of the likely pitfalls) could be provided by the gravity trip generation and distribution models. Budget allocation to (say) outdoor recreation is analogous to modelling the total number of trips generated in the gravity models.

In the short-term there is no way to implement economic analyses of congestible resource use and be certain that such analyses lead to optimal resource allocations. One approach to circumventing this potential problem is to obtain a better understanding of the salient objectives for management of congestible recreation resources. For example, if economic efficiency is not an objective, or is not salient, the current inability to apply methods analysing efficiency of alternative facility use levels and allocation methods is of no or little importance. Alternatively, if revenue objectives are salient, then Marshallian demand data provide all the information necessary to meet resource allocation performance targets. Research could be targeted at identifying whose preferences are important with respect to particular facilities, and what those people think are important outcomes of facility management. areas of research which may potentially be addressed by disciplines such as political science, law, and social sciences. This approach has the potential to sidestep the difficulties of application of economic theory, but may equally reinforce the need to discover ways to allow its application.

Without Hicksian demand information it is not possible to know if use of a facility is being allocated efficiently. However, it may be possible to identify "indicators" of efficient allocation. Such indicators may be able to be constructed by extensions of the satisfaction model to indicate "how satisfied" facility users are and "how dissatisfied" are those not obtaining access to facilities. One immediate candidate for such a measure is Marshallian demand. Alternatively, other measures of need or merit may be used to allocate facilities. One such method is that proposed by Bryan (1979) whereby facilities are allocated preferentially to the most specialised classes of facility users, who usually have the greatest dependence on a specific mixture of resource characteristics to obtain satisfying recreational experiences.

An important aspect of allocational efficiency which has not been addressed here is transaction costs. A first step in determining whether management of use of a congestible resource is efficient is to understand what the potential benefits and costs of that management are. This is an area in which empirical work may be able to give some initial guidance, and which has not been addressed in New Zealand. Management costs include administration of the selection procedure (e.g. costs of running a lottery or of building and staffing fee collection facilities), policing, and enforcing regulations. There is obviously a problem in determining optimal levels of policing and enforcement, but it may be possible to identify approximate costs of an "acceptable" system. Some small-scale contingent valuation studies could be conducted to obtain approximations to average benefits if use levels were reduced. These "potential benefits" could then be compared to the "likely costs" to provide an indication of whether any management is likely to provide net benefits. It is possible that management costs are so high that open-access remains the most efficient allocation method, at least in the short-term. If this approach were to be initially targeted at the "most crowded" facilities or "the places to avoid", an indication of negative net benefits would be indicative of a situation in which there is unlikely to be any potential gain from managing congestion at any facility. If positive net benefits were indicated, facilities which are lesser problems could be examined to provide some guidance on the conditions which signify potential gains from congestion management.

A further potential area of useful research is in understanding attitudes toward risk. The clearest policy guidance with respect to lottery-based allocation mechanisms was obtained by making an assumption of risk-neutrality over the chances of obtaining access to use specific facilities. In cases where resource users are risk-loving or risk-neutral and a facility is managed to maximise benefits obtained by facility users, the lottery is preferred to pricing as an allocation mechanism. It is therefore useful to undertake research to identify (potential) resource users' attitudes to risk, firstly to indicate their general attitudes to risk, and secondly to gain some indication of the strengths of risk-aversion and risk-seeking where they exist. Only in this way can a true evaluation of the efficiency costs of lottery allocation mechanisms, and the efficient capacities under those mechanisms, be obtained.

In conclusion, at present we have well developed economic theory for the efficient allocation of congestible recreation facilities, but do not have the ability to measure demand to put this theory into practice. If economists want to see a more rational approach to allocation of congestible resources they must devise new methods for measurement of non-marketed demands. However, the importance of undertaking the research needed to do this can only be gauged once the salience of efficiency as a management objective is known.

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# APPENDIX A

# A WORKED EXAMPLE

## Introduction

This appendix presents an example of a two good world in which one good is congestible and the other not. All demand curves are derived from a utility function. In general terms, for an individual this function takes the form[1]:

$U = U(X_1, X_2, Z)$

where $X_1$ is the quantity of the congestible good consumed by the individual,

$X_2$ is the quantity of the "normal" good consumed by the individual, and

$Z$ is the total quantity of the congestible good which is expected to be consumed - i.e. "expected use", crowding, or quality of good 1.

To be consistent with economic theory a utility function must satisfy some simple axioms. These are:

1) Utility increases with additional consumption of any good,

2) Marginal utility of consumption declines with increased consumption,

3) Utility declines with increased "expected use" of the congestible resource (*ceteris paribus*). In other words, since quality is inversely related to expected use, utility increases with quality,

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[1] Note that, to simplify expressions, the notation used in this appendix is different to that used elsewhere in this thesis. $X_1$ corresponds to $X^d$, and $Z$ corresponds to $X$ in other places.

4) If the congestible good is not consumed, utility is independent of expected use of the congestible good.

These conditions may be expressed mathematically as:

$$\frac{\partial U}{\partial X_i} > 0 \qquad i = 1, 2 \tag{A1}$$

$$\frac{\partial^2 U}{\partial X_i^2} < 0 \qquad i = 1, 2 \tag{A2}$$

$$\frac{\partial U}{\partial Z} < 0 \tag{A3}$$

$$\left.\frac{\partial X_2}{\partial Z}\right|_{X_1=0} = 0 \tag{A4}$$

Many utility functions satisfy these conditions. The following function is chosen because of its mathematical tractability. It is of separable form, which is not fully realistic. This form has been chosen purely for convenience. Utility functions of the form $U=f(X_1,Z)+g(X_1,X_2)$ would be more realistic, but greatly increase the computational difficulties without adding further insight.

$$\text{Let,} \quad U = \left[\frac{(X_1-1)}{(X_1+2)} + \frac{1}{2}\right]\frac{1}{(1+Z)} + \frac{(X_2-1)}{(X_2+2)} \tag{A5}$$

## Marshallian demand curves

The individual's Marshallian constant crowding demand functions are found by choosing $X_1$ and $X_2$ to maximise utility, subject to the budget constraint and expected use. The first-order, necessary conditions for an internal maximum are:

$$\frac{\partial U}{\partial X_i} = \lambda P_i \qquad i = 1,\ 2 \qquad \text{where } \lambda \text{ is the Lagrange multiplier} \tag{A6}$$

$$Y = P_1X_1 + P_2X_2 \qquad \text{where Y is income} \tag{A7}$$

Solving Conditions A6 and A7 for $X_1$ as a function of the other parameters yields the individual's Marshallian constant crowding demand function[2]. For the congestible good this is:

$$X_1^M = \frac{(Y + 2P_2 - 2\sqrt{P_2}\sqrt{1+Z}\sqrt{P_1})}{(P_1 + \sqrt{P_2}\sqrt{1+Z}\sqrt{P_1})} \tag{A8}$$

Alternatively, this function may be inverted to yield marginal willingness to pay as a function of actual and expected use:

$$P_1 = \left[\frac{-(X_1^M+2)\sqrt{P_2}\sqrt{1+Z} \pm \sqrt{P_2(X_1^M+2)^2(1+Z) + 4X_1^M(Y+2P_2)}}{2X_1^M}\right]^2 \tag{A9}$$

---

[2] The partial derivatives are:

$$\frac{\partial U}{\partial X_1} = \frac{3}{(1+Z)(2+X_1)^2}$$

$$\frac{\partial U}{\partial X_2} = \frac{3}{(2+X_2)^2}$$

$$\frac{\partial^2 U}{\partial X_1^2} = \frac{-6}{(2+X_1)^3(1+Z)} < 0 \qquad \text{when } X_1>-2 \cap Z>-1$$

$$\frac{\partial^2 U}{\partial X_2^2} = \frac{-6}{(2+X_2)^3} < 0$$ when $X_2$ [illegible]

## Market demand curve

The market demand curve is obtained by setting Z equal to $X_1^M$ in the aggregate Marshallian constant crowding demand function and solving for $X_1^M$. Suppose that Equation A9 represents aggregate Marshallian demand for a congestible resource, then Equation A10 must be solved for $X_1$ to obtain the market demand curve.

$$X_1P_1 + (2+X_1)\sqrt{1+X_1}\sqrt{P_1}\sqrt{P_2} - Y - 2P_2 = 0 \qquad \text{A10}$$

Equation A10 is clearly difficult to solve. It is much easier to solve for $P_1$ by setting Z equal to $X_1$ in Equation A9, yielding a quadratic function in $P_1$. Restricting interest to the smaller roots, the inverse market demand curve for the congestible good is:

$$P_1 = \left[\frac{-(X_1+2)\sqrt{P_2}\sqrt{1+X_1} + \sqrt{P_2(X_1+2)^2(1+X_1) + 4X_1(Y+2P_2)}}{2X_1}\right]^2 \qquad \text{A11}$$

## Hicksian demand curves

The Hicksian-compensated constant crowding demand curves are found by choosing $X_1$ and $X_2$ to minimise expenditure, subject to obtaining a predetermined level of utility. The first-order, necessary conditions for an internal minimum are:

$$\frac{\partial U}{\partial X_i} = \lambda P_i \qquad \text{as before} \qquad \text{A12}$$

$$U(X_1,X_2,Z) = U_0 \qquad \text{where } U_0 \text{ is the base level of utility} \qquad \text{A13}$$

Solving Conditions A12 and A13 for $X_1$ yields:

$$X_1^H = \frac{2(U_0-1) + 3\sqrt{\dfrac{P_2}{(1+Z)P_1}}}{1+\dfrac{3}{2(1+Z)} - U_0} \qquad A14$$

or, inverting:

$$P_1 = \frac{9P_2}{(1+Z)\left[X_1^H\left(1-U_0+\dfrac{3}{2(1+Z)}\right) - 2(U_0-1)\right]^2} \qquad A15$$

In the terminology of Chapter 4, $P_1$ in Condition A15 is equal to $\phi(X_1^H,Z)$.

## Plotting particular values

Table 5 identifies some points on representative aggregate constant crowding demand curves with initial parameters $Y=100$, $P_1=2$, $P_2=50$. The underlined entries in Table 5 represent points on the market demand curve. The shaded cells represent the reference point from which the Hicksian-compensated constant crowding demand curves are derived.

All demand curves exhibit negative slopes, with the Hicksian-compensated constant crowding demand curves being steeper than their Marshallian counterparts. The market demand curves intercept the Marshallian constant crowding demand curves from above, indicating that points on the market demand curve do indeed represent stable equilibria.

**Table 5:** Demand for a congestible good as a function of the expected level of use (Z) and own-price ($P_1$).

| $P_1$ | Z=5.45 | | Z=4.50 | | Z=0.00 | |
|---|---|---|---|---|---|---|
| | Hicksian Demand | Marshallian Demand | Hicksian Demand | Marshallian Demand | Hicksian Demand | Marshallian Demand |
| 1 | 8.31 | 8.66 | 8.71 | 9.49 | 9.41 | 23.03 |
| 2 | 5.45 | 5.45 | 5.75 | 6.02 | 6.48 | 15.00 |
| 3 | 4.18 | 4.04 | 4.44 | 4.50 | 5.18 | 11.51 |
| 4 | 3.43 | 3.21 | 3.66 | 3.60 | 4.41 | 9.47 |
| 9 | 1.80 | 1.47 | 1.98 | 1.71 | 2.74 | 5.22 |
| 12 | 1.36 | 1.02 | 1.52 | 1.23 | 2.30 | 4.14 |
| 16 | 0.98 | 0.64 | 1.13 | 0.82 | 1.91 | 3.24 |
| 200 | --- | --- | --- | --- | 0.12 | 0.00 |

## Social welfare maximisation

Knowledge of the aggregate Hicksian-compensated demand function allows estimation of the price and use levels which maximise social benefits (from Equation 4.11). The necessary condition for such a maximum when Equation 15 represents aggregate Hicksian demand is:

$$\int_0^{Z^*} \left[ \frac{\left(\frac{3}{2}X_1 - (1+Z^*)(1-U_0)(X_1+2)\right)}{\left((1+Z^*)(1-U_0)(X_1+2) + \frac{3}{2}X_1\right)^3} \right] dX_1 \qquad \text{A16}$$

$$= -(1+Z^*)^{-1} \left[ Z^* \left( 1 - U_0 + \frac{3}{2(1+Z^*)} \right) + 2(1-U_0) \right]^2 + MC(Z^*)$$

Solution of this condition requires elimination of the unknown $U_0$. This is achieved through use of the market demand curve (Condition A11) and the budget constraint (Condition A7) to substitute for $X_2^*$ in terms of $Z^*$ in the utility function $U^*=U(Z^*,X_2^*,Z^*)$. Solution of Equation A16 is clearly not straightforward, even when marginal supply costs are zero, so is not pursued here. Equation A16 is presented to show that identification of the efficency maximising point is possible, however, it's format indicates that numerical approaches to identification of this point may often be simpler than the differential calculus route.

## Effects of a price change

This section determines the effects of a change in price for the congestible good. Initial parameters are:

$$Y = 100, \quad P_1 = 2, \quad P_2 = 50$$

From the market demand curve it is found that, with these parameters, 5.4475 units of good 1 and 1.7821 units of good 2 are consumed. Substituting these parameters in Equation A5 reveals that utility equals 0.3770 units.

The consequences of changing the price of good 1 are now investigated. Let $P_1=3$. From the market demand curve:

$$X_1 = 4.4959$$

Letting $Z=4.4959$ and $U_0=0.3770$, the relevant constant crowding demand curves are:

$$X_1^M = \frac{200 - 33.1539\sqrt{P_1}}{P_1 + 16.5769\sqrt{P_1}} \qquad \text{A17}$$

$$X_1^H = \frac{10.0990}{\sqrt{P_1}} - 1.3907 \quad \equiv H^0 \qquad \text{A18}$$

Evaluating these demands at $P_1=2$ gives $X_1^M = 6.02$ and $X_1^H = 5.75$ (see Table 5). In this case the partial derivative with respect to quality of the Hicksian-compensated constant crowding demand curve is indeed less than the Marshallian version of the same derivative, in accord with the analysis of Section 7.4.

At $P_1=3$ the quantities of good 1 demanded are $X_1^M = 4.50$ and $X_1^H = 4.44$. While the difference between Marshallian and Hicksian demands is small (less than 1.5%) in this case, it is not due to rounding error. The difference illustrates that the two constant crowding demand curves for the new quality level ($Z=4.4959$) do not intersect at the price necessary to sustain that quality level. An alternative method of arriving at the same conclusion is to derive the Hicksian-compensated constant crowding demand curve through $X_1=4.4959$, $X_2=1.7302$ - the market demands when $P_1=3$. Under these conditions $U_0= 0.3847$, and the Hicksian constant crowding demand curve is:

$$X_1^H = \frac{10.1877}{\sqrt{P_1}} - 1.3856 \quad \equiv H^1 \qquad \text{A19}$$

Clearly, since there is no real intersection of the two Hicksian constant crowding demand curves ($H^0$ and $H^1$), they cannot intersect at $P_1=3$.