bushfire CRC

A GUIDE FOR ESTIMATING THE NON-MARKET VALUES ASSOCIATED WITH IMPROVED FIRE MANAGEMENT

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Preface

Non-market valuation techniques are required for estimating the value of environmental, social and other impacts of bushfire management for use in cost-benefit analysis. This guide has two goals. The first is to demonstrate how the non-market benefits and costs associated with bushfire management can be estimated. This includes market-based, revealed preference and stated preference techniques, with emphasis on the latter two approaches. Each of these approaches is described and explained to provide analysts working in this area with an in-depth understanding of how each of the techniques works, and many of the critical issues that are involved in applying them. The second goal of the manual is to summarise the existing literature on the non-market values associated with bushfire prevention. This includes studies conducted in Australia and overseas, particularly the USA.

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1. Introduction

In any area of government expenditure, such as bushfire prevention, a challenge for policy makers is to ensure that an appropriate amount of funding is allocated, and that the money allocated is expended effectively. Economics provides a framework, known as cost–benefit analysis, for achieving these goals. The identification of the social or community-wide costs and benefits of particular projects enables the calculation of benefit–cost ratios and net benefits of each of the projects. This allows, firstly, the identification of those projects that will produce the greatest benefit for the community and, secondly, provides a case for increasing overall government funding where it can be demonstrated that this will have high net benefits for the community. In recent years, there have been various calls for the use of cost–benefit analysis for bushfire management (e.g. Ganewatta and Handmer 2006) and several attempts at operationalising this framework in the context of bushfire management in Australia (e.g. Bennetton et al. 1998, Gunasekara et al. 2005).

Cost-benefit analysis requires that all the benefits and costs associated with a project, program or policy be identified and converted into dollar values, and thus is different to a simple financial analysis where only direct outlays and income are considered. All non-financial impacts on society, such as social and environmental impacts, need to be identified and monetarised.

For bushfire management, the identification of the social and economic benefits is relatively straightforward. As noted by Esplin, Gill and Enright (2003) in the *Report of the Inquiry into the 2002–2003 Victorian Bushfires*, impacts include such things as loss of forests, homes, farms, fences and stock. There are also various community impacts such as loss of jobs, (potable) water quality problems, and reduced infrastructure and amenity, as well as various psychological impacts, such as fear, stress, shock, fatigue and frustration.

Venn and Calking (2008) provided a useful summary of the positive and negative effects of bushfires on non-market resources, shown in Table 1. Their original table has been adjusted for the Australian context and extended to include social impacts. It is apparent that fire management produces a range of economic values. These have been classified as losses that may result from a bushfire associated with recreation, damage to flora and fauna, problems with air, soil and water quality, damage to cultural heritage, large-scale carbon emissions and social disruption. At times, however, fires may have some offsetting benefits, for example, for recreation as well as flora and fauna.

Table 1: Positive and negative effects of bushfire on non-marketed resources that are valued by society

	Positive fire effects	**Negative fire effects**
Recreation	• Improved wildflower and wildlife viewing • New scenic vistas may be revealed • Previously hidden historical sites may be revealed (e.g. important Aboriginal sites were revealed following the 2003 Victorian fires) • Novelty of a burned forest • Removal of undergrowth providing improved access to area	•Restricted access to areas impacted by fire •Closure of areas due to unsafe conditions •Campsites and associated infrastructure (tracks, paths, facilities, information boards) destroyed • Debris on hiking, biking and four-wheel-drive trails • Burned forest may be aesthetically displeasing • Short- to medium-term reduction in fishing success due to stream habitat deterioration • Increased risk perception causing people to avoid areas because they believe it is dangerous • Redirection of land-management staff away from recreational support activities to fire clean-up, etc.
Flora, fauna and invasive species	• Short-term increase in wildlife foods and habitat diversity often increases the numbers of individuals and species of birds, mammals, reptiles, terrestrial amphibians and insects • Low-severity fire will favour native plants adapted to wildfire and facilitate ecosystem restoration • Conservation of locally rare plants is improved by diverse disturbance histories • Diverse disturbance histories likely to reduce the potential for epidemic insect and disease infestations • Long-term improvement of aquatic habitat quality	• Decades of fuel accumulation due to fire suppression mean that contemporary wildfires have a greater probability of being large, severe and stand-replacing. This may have long-lasting negative ecological consequences, particularly for threatened and endangered flora and fauna • Short-term highly negative impact on stream amphibians and fish • Some exotic plant species are adapted to colonise post-fire landscapes
Air quality		• Human respiratory health • Reduced visibility at scenic vistas and on roadways • Soiling of surfaces of objects
Soil	• Short-term increased availability of nutrients for plant growth	• Soil structure is lost (reducing soil porosity) • Nutrients are volatised or made susceptible to loss through leaching and surface runoff • Soils may become hydrophobic • Acceleration of wind and rain erosion, and dry ravel
Water quality		• Increased peak flood flows, and increased sediment and debris washed into waterways can damage or reduce the effective life of infrastructure including bridges, dams, water distribution systems and hydroelectric power turbines • Impaired suitability of water for municipal and other purposes, which increases water treatment costs
Cultural heritage	• Wildfire consistent with historical fire regimes is likely to maintain or enhance cultural heritage	• Uncharacteristic wildfire may be detrimental to or destroy cultural heritage

Carbon emissions and stocks	• Wildfire limits fuel accumulation such that future wildfires will be less severe and emit less carbon	• Potentially large immediate release of sequestered carbon
Social disruption		• Loss of homes, community infrastructure, road closures • Individuals leaving area owing to loss of employment or income-generating opportunities • Individuals leaving the area owing to loss of support services or infrastructure • Loss of items of individual or personal value • Post-traumatic stress (treated and untreated and its associated impacts)

Source: Venn and Calkin (2008), with some additions

While it is relatively straightforward to identify the social benefits and costs associated with bushfire management, the second step of assigning dollar values to these benefits and costs is, however, less easy. Non-market valuation techniques are generally required to estimate many of these benefits and costs. These techniques use information from related markets or information obtained through community surveys to identify the monetary benefits and costs associated with goods that are not traded in markets. In Australia, there is, however, relatively little information available about the extent of these non-market values. Bennetton et al. (1998, p. 163) noted that there was a 'dearth of fire specific studies' and identified only two Australian studies that had sought to estimate any of the values listed in the table above, both of which focused on lost recreation value (Bennett 1984, Loane and Gould 1986). Since then, only one Australian study has been conducted focusing explicitly on the benefit to the community of reducing fire in bushland (Concu 2007). Because of the scarcity of these value estimates, it has not been possible to estimate the value of all of the social and environmental impacts in cost–benefit analyses associated with fire management, and there have been calls for the greater use non-market valuation techniques to improve economic analyses associated with bushfire management (e.g. Gunesekara et al. 2005b, Ganewatta and Handmer 2006)

The goal of this manual is firstly to demonstrate how the non-market benefits and costs associated with fire management can be estimated. In the environmental economics literature, a range of techniques, including what are known as market-based, revealed preference and stated preference techniques, is available for estimating these values. Each of these approaches is described and explained here, with the aim of providing an in-depth understanding of how each of the techniques works and many of the critical issues that are involved in applying them. However, as this manual is not exhaustive, more detailed references are also recommended for use if one is planning to apply a given technique.

The second goal of the manual is to summarise the existing literature on the non-market values associated with bushfire management. While there have been few studies conducted in Australia, many have been conducted in the context of bushfire management overseas, particularly in the USA. There have also been other studies not conducted in the context of bushfire management but nonetheless relevant to it (e.g. the costs of lost jobs, the costs of electricity and water outages). Therefore, at the end of this manual, a summary of these non-market valuation studies is given to assist with future cost–benefit analyses in the area of fire management.

2. Economics Values and Fire Management

Before demonstrating how to estimate the non-market values associated with improving fire management, it is important to understand what is meant by *economic value*.

Use Values

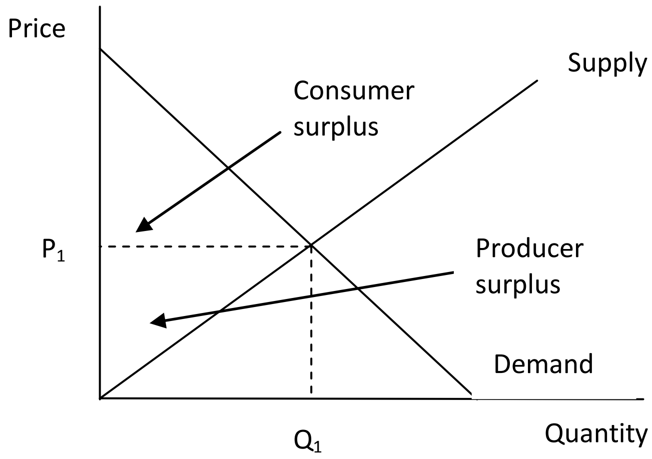
Economic value comprises what are known as use values and non-use values. As their name suggests, use values result from the *in situ* use as well as the indirect use of resources. For example, direct use values might include recreation such as bushwalking or fishing, enjoyment of clean air and water, timber and other agricultural production. Indirect use values result from changes in ecosystem services. For example, a bushfire may lead to increased turbidity which could affect water treatment costs. While many use values can be estimated using market data (e.g. value of lost timber production), many, such as those listed above that are not traded goods cannot be estimated directly, and non-market valuation techniques need to be applied.

Consumer and Producer Surplus

From an economic perspective, the use value from a particular activity (e.g. timber production, recreation) is measured as the sum of the consumer and producer surpluses from the activity. Consumer surplus represents the benefits from consumption of a good or service It is equal to the difference between what people are willing to pay and what they actually pay, given by the area below the demand curve but above price P_1 (see Figure 1). Intuitively, one can see why consumer surplus indicates consumer welfare: it is because it shows the net benefits to consumers from consumption.

The benefits from the production of goods and services are called the producer surplus. This is the difference between what producers are willing to sell for (their marginal cost) and price. Hence, it is equal to the area above the supply curve and below price P_1 (see Figure 1). Use values can be calculated by adding together producer and consumer surpluses.

Figure 1: Consumer and producer surplus



Option Value and Option Price

Option value was first described by Weisbrod (1964) and reflects the value that individuals place on uncertainty. In the economics literature, option value is separated into two different types: demand-side and supply-side option values. Demand-side relates to uncertainty about one's use of a natural resource. For example, the manager of recreation at a national park can statistically determine how many people will visit the park in a particular year and potentially estimate their willingness to pay. However, there may be people who will never actually visit the park but would nonetheless be willing to pay to ensure that it remains open. For this reason, the earliest writers on demand-side option thought that it would always be positive (Weisbrod 1964, Cicchetti and Freeman 1971).

There may also be people who when asked their willingness to pay are uncertain about whether they will actually use the resource. Consequently, their willingness to pay may in fact be lower than that of those who are certain they will use the resource, meaning that for some people, demand-side option value could be negative. This possibility led later writers to conclude that the sign of option value was in fact indeterminate (Schmalensee 1972, Anderson 1981, Bishop 1982).

Supply-side uncertainty occurs when the future provision of a good is uncertain. Although the sign of demand-side option value is indeterminate, the sign of supply-side option value can in most cases be determined. An example would be when there is uncertainty about access to a resource, and a new project or a policy change will eradicate this uncertainty. In this case, supply-side option value is positive; that is, people would be willing to pay a premium to remove this uncertainty (Bishop 1982, Freeman 1985).

At this point, one may wonder whether option value is simply a theoretical curiosity given the uncertainty about its sign. The main implication from the literature is that researchers should be careful not so much to estimate option value, but instead *option price*. Option price is the sum of consumer surplus (in the absence of uncertainty) and option value. Estimating option price, which means that one estimates consumer surplus but also allows for uncertainty in either demand or supply in the estimation process, should be adequate in most cases. This point is made by Bishop (1982, p. 14):

> *On an empirical level, the primary contribution of literature reviewed here may not be option value, but option price. Few would object to the assertion that if it could be measured, option price rather than projected consumer surplus is the correct measure of consumer welfare in cases involving considerable uncertainty. Furthermore option price would appear to be much more amenable to measurement than option value taken alone.*

Existence or Non-Use Value

Existence value is known by several names, including non-use value and passive use value. Existence value reflects individuals' willingness to pay to preserve a resource apart from any *in situ* use. Krutilla (1967, p. 781), who first suggested existence values, commented that:

> *When the existence of a grand scenic wonder or a unique and fragile ecosystem is involved, its preservation and continued availability is a significant part of the real income of many individuals.*

Put another way, Krutilla (1967, p. 781) wrote:

> *There are many persons who obtain satisfaction from mere knowledge that part of wilderness North America remains even though they would be appalled by the prospect of being exposed to it.*

These existence values may result for various reasons, including bequest, altruistic, stewardship and self-seeking motives. The magnitude of existence value depends on factors such as the existence of close substitutes and the supply of the resource (Randall and Stoll 1983). Existence value is typically associated with the natural environment, such as unique ecosystems; however, more recent research suggests that existence values may also accrue for human activities such as the preservation of rural employment (Portney 1994, Morrison, Bennett and Blamey 1999). For the most part, existence value is considered to be positive, though in some cases it has been found to be negative, such as for environmental pests (e.g. coyotes; see Stevens et al. 1991).

Total Economic Value

Total economic value is the overall value that an individual has for a good. It includes use-related values (use value and option value) and non-use related values (existence values).

Total economic value = use value + option value + existence value

This concept is the most relevant measure of value for most economic analyses.

While it may be possible to separately estimate use, option and existence values through, for example, careful wording in a questionnaire, it is more often the case that individuals make holistic judgements about the value of a good. As Mitchell and Carson (1987, p. 83) have suggested:

> *Our view of respondent behaviour in the CV [contingent valuation] setting is that when people are asked to value an amenity … they do so by making a holistic judgement. Instead of going through a mental process where they separately value each of the relevant benefit categories (such as use and existence values) before combining them in their minds to arrive at total value, respondents arrive at a global judgement about what the amenity is worth to them...*

Therefore, it is likely that respondents form an assessment of the overall value that they have for a change in the quality or quantity of a natural resource and unlikely that they separately calculate and add up their use, option and existence values to determine their total willingness to pay. The implication is therefore that it is appropriate in stated preference studies to estimate total economic value, rather than the magnitude of each of its components. An important point in any discussion of total economic value is that total economic value can only generally be estimated for marginal changes in environmental quality. It is possible, for example, to estimate the total economic value associated with a policy alternative. But it is not possible to identify the total economic value of an environmental resource (eg a forest). This is because it is only possible to estimate non-use values for marginal changes in environmental quality.

3. Market-Based Approaches

Now that the values associated with bushfire prevention have been described, we consider the different approaches that can be used to estimate them, beginning with market-based approaches.

It is sometimes possible to derive estimates of use values associated with bushfire prevention from existing market data. For some goods, this is relatively straightforward, such as the value from loss of timber production. For other aspects of the damage caused by a bushfire, estimates of value may be derived by identifying damage costs or preventative expenditures. For example, the benefits of better water quality from preventing bushfires can be inferred from the reduced cost of treating potable water (e.g. Loomis et al. 2003), and similarly the benefits of better air quality from preventing bushfires can be inferred by estimating the reduced health-related costs from increased air pollution (e.g. Glover and Jessup 1999, Butry et al. 2001). The replacement costs for roads or community infrastructure, such as schools, also provide a lower-bound estimate of their value to the community. However, one of the limitations of using market-based approaches is that they only provide a lower bound on community values as the community may be willing to pay more than the replacement cost to prevent damage by bushfire.

Many of the values summarised in Table 1, however, can only be estimated by using revealed or stated preference techniques, which are described next.

4. Revealed Preference Techniques

Revealed preference techniques use information from related markets to impute a value for non-market goods. A related market is one that indirectly reveals values for a good; that is, there is some relationship between what you are trying to value and the market that allows you to impute a value. The most commonly used revealed preference techniques are the hedonic price and travel cost methods.

Hedonic Price Method

Hedonic pricing is based on the idea that a person's preferences for different goods (such as housing, jobs, types of wine) depend on the features or attributes of those goods. For example, a person's willingness to pay for a property will reflect the attributes of that house, including the number of bedrooms and bathrooms, size of backyard and proximity to schools. Using statistical methods, it is possible to control for many aspects of people's real estate choices (such as number of bedrooms) and isolate the effect of the features to be valued, such as proximity to bushland or access to infrastructure.

Hedonic price analysis relies on the use of multiple regression analysis. This involves estimating a mathematical function using the data collected, in this example showing how house price changes as the various attributes or characteristics of a house changes. In a hedonic study by Boyle et al. (1999) that involved valuing water quality at a lake, the regression equation for one market was estimated as follows:

Sales price = 25,899 + 6790·ln(SQFT) + 83·FRONT – 3919·DNSTY + 1516·DIST + 11,572·HEAT + 23,465·BATH – 17,579·LKWATER + 2.057·WQ

The independent variables were: square feet of the structure on the property (SQFT); the length of the property frontage on the lake (FRONT); number of lots per 1000 feet of frontage adjacent to either side of the property (DNSTY); the distance between the property and the nearest town (DIST); and dummy variables to indicate whether the structure had central heating (HEAT), a full bath (BATH) or if the property used lake-water as its primary source of water (LKWATER); and a measure of water quality (WQ).

This equation demonstrates that the water quality of the lake does have an influence on sales price, and hence a value for a change in water quality can be imputed by identifying the effect on house prices.

A hedonic price analysis is typically carried out from the estimation of a single equation such as this. The example above requires the collection of property sales data and data about the features of the property, all of which are now quite accessible in Australia. This can be combined with socio-demographic information, which is available from the Australian Bureau of Statistics at a collection district level (every 200 households). GIS (Global Information Systems) can then be used to calculate such things as distance to infrastructure and natural assets.

A couple of studies have used hedonic pricing to estimate the damage cost to houses from bushfires. For example, Huggett (2003) found that fires in the Wenatchee National Forest in the USA decreased house prices near the burned area for six months after the fire, though property prices rebounded after that period. In contrast, Loomis (2004) found that property prices in a town two miles from the Buffalo Creek Fire in Colorado were 15–16% lower five years after the fire than they would have been if it had not occurred. According to Loomis (2004), this was due to an increase in perceived risk of wildfires as well as reduced amenity values. Although not the goal of either of these studies, it may also be possible to estimate the change in property prices from loss of access to certain infrastructure (roads, schools, etc.).

Most hedonic price analyses previously conducted in Australia have been 'single-stage' analyses, similar to the studies just described. In a single-stage analysis, implicit prices for various attributes (such as number of bedrooms and bathrooms) are estimated. An implicit price represents the willingness to pay for a particular attribute given a fixed supply of the attribute of interest.

More recently, more refined hedonic techniques have been developed that enable researchers to estimate the demand for particular housing attributes (e.g. water quality, noise levels) and derive more accurate estimates of willingness to pay than is possible with single-stage analyses. These approaches have required either (1) the conducting of multiple single-stage hedonic analyses in geographically separate housing markets to enable modelling of substitution effects; or (2) surveys of households to collect information about the socio-demographics of the household for each house sale in the data set (Taylor 2003). However, both of these approaches are very data-intensive and thus most hedonic price analyses remain single-stage analyses.

For the interested reader, an excellent overview of the hedonic price method is provided by Taylor (2003).

EXAMPLE: Loomis (2004)

Loomis (2004) conducted a single-stage hedonic price analysis to determine if there was a decrease in property prices in the town of Pine, Colorado, two miles from a major wildfire that burned 12,000 acres and destroyed 10 houses in the small town of Buffalo Creek.

He estimated both linear and semi-log regression models; the former is reported here. In this model, house prices are a function of acreage, whether a house has a fireplace, whether a house has a garage, the number of bathrooms, the year in which the home was built, the underlying trend in house prices and whether the house was sold prior to or after the forest fire.

The following linear regression equation was estimated. All model coefficients were significant (absolute value of the *t*-statistics greater than 1.96), meaning that each of these coefficients significantly influences house prices. The coefficient for post-fire is –17095, which means that after the fire, prices on average fell by $17,095 per property, or about 15%.

Table 2: Linear hedonic price regression equation (from Loomis 2004)

Variable	Coefficient	*t*-statistic
Constant	–1614848	–7.643
Garage	18512.38	3.539
Fireplace	16073.97	4.664

No. of bathrooms	21600.63	8.056
Year built	399.16	4.188
Acreage	332.22	5.398
Trend	24.60	7.813
Post-fire	–17095.53	–2.131
Adj. R^2	0.515	

Travel Cost Method

A second revealed preference technique is the travel cost method, which is used to value recreational quality or changes therein. The basic idea of the travel cost method is that information on travel costs and reductions in the number of site visits from greater distances can be used to estimate a demand curve for recreation, and thus recreational use value. This technique is regularly used by State government agencies such as the NSW National Parks and Wildlife Service to estimate recreational values (Gillespie 1997). The demand curves generated from such analyses are often used in setting optimal prices, for example, for entrance to national parks. This approach is of relevance for bushfire prevention in understanding the sorts of recreational values that are lost through fires.

There are several different types of travel cost method; the zonal travel cost model, the individual travel cost model and the random-utility travel cost model are now described.

Zonal Travel Cost Model

The basic idea of a zonal travel cost model is to try to identify how the *proportion* of people that visit a site from a particular area changes with distance and therefore travel cost.

The first step in estimating a zonal travel cost model is to define the zones where visitors to a recreation site come from. These zones are effectively geographical areas or regions, and could include, for example, local government areas. Once these zones are defined, one then calculates the number of visitors to the site per 1000 population within the region. The travel cost to each of the regions is then specified, and a regression equation is estimated where the dependent variable is the number of visitors per 1000 population in each region and the independent variable is travel cost. Typically, linear or logarithmic regressions are estimated at this stage.

In the second step, a range of hypothetical prices associated with the use of the resource is entered into the regression equation to determine the number of visitors at each price. In order to estimate a demand curve, information is needed about how quantity demanded changes with price. Hence, the number of visitors at each price point are used as inputs into a second regression equation that is used to estimate a demand curve from which consumer surplus is estimated.

The zonal travel cost model provides two main outputs: (1) estimates of the consumer surplus associated with recreation, and (2) information about how the quantity of visitors changes with entrance fees. It does not provide any information about how recreation value or visitation changes with site quality or the quality and availability of substitutes and so on (unlike the individual travel cost model or the random utility travel cost model; see below). Hence, in the context of bushfire management, this approach is likely to be less useful than the other travel cost approaches.

There are various issues that must be resolved in applying the zonal travel cost model, such as how to treat multiple-site or multiple-purpose visits, how to treat visits lasting multiple days, how to treat vehicles that have multiple people in them and how to value travel time (issues that similarly apply to the individual travel cost model). Alternatives for dealing with these issues are discussed in Bennett (1995) and Gillespie (1997)[1].

EXAMPLE: Gillespie (1997)

Gillespie (1997) conducted a zonal travel cost study to estimate the recreational use value of the Minnamurra Rainforest Centre, Budderoo National Park, NSW.

Visitation surveys were first conducted and respondents were specified as visiting from one of nine travel zones. The annual visitation rate per 1000 population and vehicle plus travel time cost were then calculated for each of the nine zones.

Table 3: Estimates of annual visits per thousand people, return distance and travel costs

Zone	Annual visits (per 1000 popn)	Return distance (km)	Vehicle plus time cost ($)
Illawarra – local	149.59	30	4.38
Illawarra	99.42	86	10.81

[1] Travel time is normally valued at some fraction of the normal wage rate (usually 20–50%). For multiple-purpose trips, various approaches have been used, including (1) apportioning costs based on the marginal distance to a site; (2) the ratio of time spent at site relative to total travel time; (3) the ratio of time spent at a site relative to the total trip time minus travel time; and (4) the perceptions of users about the relative importance of a visit to a given site (Gillespie 1997).

South-western Sydney	44.03	196	24.03
Sydney – Blue Mountains	24.24	282	26.17
ACT	22.90	466	36.81
South-eastern	15.75	420	40.78
Newcastle–Gosford	8.51	486	45.56
Country NSW and Victoria	16.83	1166	129.34
Metro. Vic., QLD and SA	2.94	2400	230.15

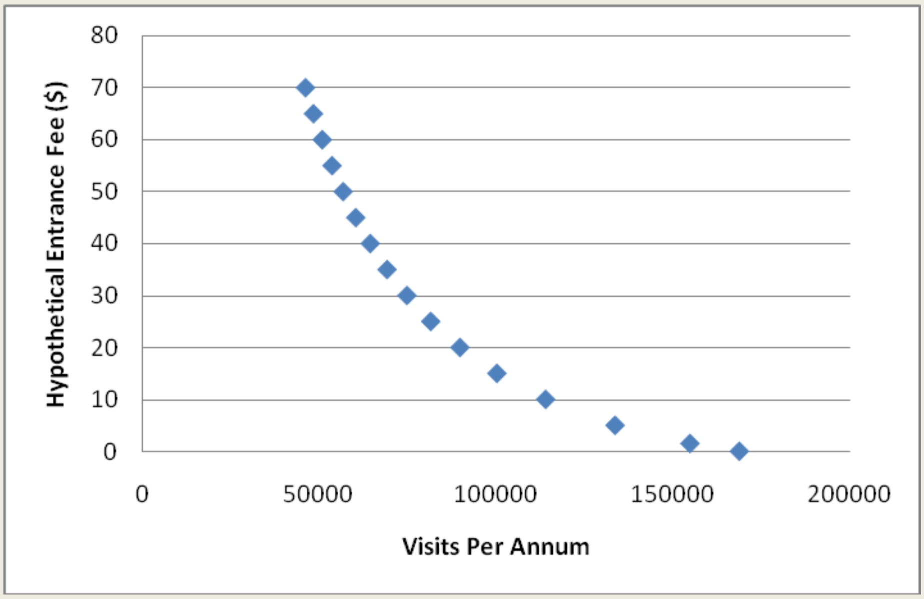
Gillespie (1997) then used these data to estimate a double log regression model as follows:

Annual visits = 0.6446 – 0.929 × Vehicle plus time cost
t-statistics (11.593) (–6.179)

R^2 = 0.845, F = 38.176

Simulated entrance fees of $0 to 100 were then used to calculate the demand curve, as shown in the figure below.

Figure 2: Demand Curve for Estimating Recreation Value



A double log regression model was again used to estimate the demand curve, which shows the relationship between entrance fees and visitor numbers, as follows:

Entrance fees = 21.549 – 1.800 × Visit numbers
t-statistics (25.664), (–21.450)

Consumer surplus was then determined by calculating the area under this demand curve through integration, with cut-offs at the existing visitation level and $100. This produced a per-visit recreation value of $44, and an annual recreation value of $6.2 million.

Individual Travel Cost Model

The individual or single-site travel cost model seeks to demonstrate the relationship between the number of visits a person takes to a recreational site over a season and travel cost and other factors. In its simplest form, the individual travel cost model is as follows:

Number of trips = f(travel cost)

However, the number of trips is not just explained by travel cost; it also depends on individuals' socio-demographic characteristics, previous experiences at the site and proximity to substitute sites (Parsons 2003). Hence, the above equation can be expanded as follows:

Number of trips = f(travel cost to site visited, travel cost to substitute sites, socio-demographic variables, perceived site characteristics)

This equation can then be estimated using regression analysis and is used for the estimation of consumer surplus associated with recreation. The procedures for applying the individual travel cost model are straightforwardly described in Parsons (2003).

The advantage of the individual travel cost model is that it explicitly allows the inclusion of substitute sites, as well as socio-demographic variables. However, the limitation of this model is that it depends on visitation declining with distance. For environmental assets where there is a small population residing close to the asset, but a much larger population further away, this assumption is unlikely to hold. In this context, the zonal or random utility travel cost models may be preferred.

While not often done, it is possible to value quality changes with an individual travel cost model, which would be useful when seeking to understand the likely effects on recreation of a serious event such as a bushfire. For example, hypothetical questions could be used to determine how visitation would change with a hypothetical change in site quality, or cross-sectional data from many sites could be included (see Parsons 2003).

EXAMPLE: Loomis, Gonzales-Caban and Englin (2001)

An example of how to generate an individual travel cost model using cross-sectional data to demonstrate the effects of changes in quality on recreation values is provided by Loomis et al. (2001). They demonstrated the effect of bushfires on recreation values associated with hiking and mountain-bike riding in the USA.

As this was a cross-sectional study, sampling had to occur at a range of different sites that had been differentially affected by bushfire. On-site sampling was conducted at various national forests. Trailheads were stratified by acres burned and year of fire, and equivalent unburned sites were sampled as control groups. A sample of 354 respondents was achieved.

Once the data were collected, the authors estimated Poisson[2] regression models where number of trips to various sites was a function of travel costs (including time), socio-demographics, fire characteristics and trail characteristics. The coefficients for the hiking model are shown in the table below. Per-person per-trip recreational value is calculated by dividing 1 by the travel cost coefficient, so 1/0.009 = $111. By including the interactions with travel cost and how long ago the fire was (age) and whether it was a crown fire, one can determine the effects of bushfires on recreation values. After five years, the recreation value had decreased to $100, and after 15 years, to $83. The reason why (perhaps unexpectedly) recreation values had decreased for hikers in the USA is that such areas experience a profusion of wildflowers after a bushfire and that over time the number of wildflowers present diminish. In contrast, for mountain-bike riders (model not reported here), Loomis et al. (2001) found the opposite, that recreation values increased with time after a bushfire.

Table 4: Poisson regression model coefficients for the hiking sample

Variable		**Coefficients**
Constant		–2.918***
Travel cost	Individual's share of reported travel costs	–0.009***
Income	Household income of the survey respondent	$-8.0*10^{-}$
Travel time	Individual's travel time to the site	0.012***
Gender	Dummy variable where 1 = male, 0 = female	0.900***
Age of hiker	Respondent's age	–0.127***
Hypothetical scenario	Dummy variable where 1 = trips in response to the contingent scenario, 0 =actual trips taken	0.634***
Lodgepole pine	Dummy variable where 1 = lodgepole pine, 0 = otherwise	–1.813***
Dirt access road	Dummy variable where 1 = dirt access road, 0 = paved road	–1.444***
Elevation	Trailhead elevation above sea level	0.0003***
FAGE	The negative of how old the fire was at recreation area: -1 = one-year-old fire, -20 = 20-year old fire	–0.023***
Crown fire	Dummy variable where 1 = crown fire, 0 =	0.155

[2] This is a type of count data model, which is suited to situations where the dependent variable is a non-negative integer.

Travel cost × FAGE	0.0002***
Travel cost × Crown	–0.0007
FAGE × Crown fire	0.023
Adj. R^2	0.72

*** significant at 1%, ** significant at 5%

Random Utility Travel Cost Model

As its name suggests, the random utility travel cost model is based on random utility theory. The central idea of this theory is that the probability of choosing one alternative over another depends on the magnitude of the utility of each alternative, and this utility can be decomposed into a systematic or explained component (V_i) and an unexplained or error component (e_i). That is,

$$P(i|i,j) = P(V_i + e_i > V_j + e_j)$$

The utility of an alternative depends on its attributes. Hence the random utility travel cost model is what we call a multi-attribute technique. That is, $V_i = f(\mathbf{X})$, where **X** is a vector of product attributes.

Put more simply, the utility of a particular recreational site, for example, might be a function of the travel cost of reaching it, the availability of camping sites, other on-site facilities (e.g. showers and toilets) and amenity values. If a linear functional form were chosen for this example, utility would be calculated as follows:

$V_i = \beta_o + \beta_1 \cdot \text{travel cost} + \beta_2 \cdot \text{camping sites} + \beta_3 \cdot \text{showers} + \beta_4 \cdot \text{amenity}$

Where β_o is the constant and $\beta_1 – \beta_4$ are model coefficients which show how a change in their respective variables changes utility.

To operationalise the random utility travel cost model, data are collected about site visits over a season (e.g. via the use of trip diaries) and what substitutes are available to those surveyed. Data on the characteristics (attributes) of each the sites visited and the substitute sites then needs to be collated.

- **Data analysis**

The probability of choosing a particular site among the alternatives available is then modelled statistically using discrete choice models. The simplest of these is known as the conditional logit model. The basic idea of the conditional logit model is that the probability of choosing an alternative is a function of the utility of that alternative relative to that of *all* alternatives. This can be expressed in the following form:

$$P_i = \frac{\exp V_i}{\sum_1^j \exp V_j}$$

where P_i is the probability of choosing alternative i, utility $V_i = \beta_0 + \beta_1 X_{1i} + \ldots + \beta_n X_{ni}$, and $X_1,\ldots,X_n$ represent the attributes of the good.

To understand how this model works, first note that "V" stands for utility and the symbol Σ in the equation means "sum of from alternatives 1 to j". What the equation is saying is that the probability of choosing an alternative is a function of the utility of that alternative relative to the utility of all alternatives. For a moment ignore the exponents (the e's). Say an alternative has a utility of 10 units, and the utility of all alternatives is 100; then the probability of choosing the alternative is 10%. However, the exponents (used to scale or transform the utility of each alternative) are included for two reasons: (1) this stops any alternative from having a negative probability of being chosen, and (2) it increasingly rewards with higher market share those alternatives with higher utility[3].

However, more sophisticated models such as nested logit models are generally used because of violations in the assumptions of the conditional logit model[4]. Parsons (2003) more fully explains the use of alternative models such as the nested logit model.

- **Calculating values**

The random utility travel cost model can be used for calculating the value of a change in quality at a single recreational site, a change in quality at multiple recreational sites, and to value the complete loss in access to one or more sites. For the conditional logit model, willingness to pay (WTP) is calculated using the following formula (Hanemann 1984).

$$\text{WTP} = -\frac{1}{\beta_M} \; \ln \sum_i \exp^{V_0} - \ln \sum_i \exp^{V_1}$$

where β_M is the coefficient of the cost attribute, V_0 represents the utility of the initial state, and V_1 represents the utility of the subsequent state (for each of the alternatives). A

[3] An example of how market share is calculated from a conditional logit model is presented in the Appendix.
[4] Notably the assumption of independently and identically distributed errors, which results in what is known as the independence of irrelevant alternatives (IIA) property. This property implies that the probability of choosing one alternative over another is independent of the presence or absence of other alternatives. This property is violated by the existence of non-independently and identically distributed (IID) errors.

somewhat more complicated formula is used for calculating values with the nested logit model.

EXAMPLE: Sandstrom (1998)

Sandstrom (1998) estimated a relatively simple random utility travel cost model of Swedish seaside recreation to determine the benefits of reduced eutrophication. He estimated both conditional and nested logit models; only the former are reported here. Visitation data from various seaside recreational areas were obtained from a travel tourism database, which is based on monthly samples of several thousand Swedes. Utility of a particular area for recreation (V) was modelled as being a function of travel cost, sight depth[5], the number of beaches in the area, the number of alcohol-serving licences per thousand people (a proxy for night-life) and the average hours of sunlight per month. Travel cost included both actual expenditures and an allowance for travel time. The following parameter results from the conditional logit model were estimated for on-shore recreationalists (see Table 5).

Table 5: Conditional logit model for beach recreation

Variable	Coefficients
Sunlight	0.299
Travel cost	–0.00101
Sight depth	0.575
Number of beaches	0.0207
Licences	0.544

Note: All variables were significant at the 1% level

Before estimating values from a quality change, Sandstrom (1998) first needed to quantify the relationship between sight depth and nutrient levels, which he did by estimating a regression equation. He then estimated the effect on sight depth from a 50% reduction in nutrient levels in Laholm Bay in south-west Sweden, one of the most badly affected sites.

He used the results from the conditional logit model and Hanemann's (1984) formula (see above) to estimate the per-person willingness to pay for this improvement in sight depth. These results were generalised across the population, and it was estimated that the increase in recreational value from this quality improvement was 12 million kronor.

[5] Water quality was measured using sight depth data. A regression equation was estimated showing that sight depth was a function of water temperature and both nutrient and phosphorus levels.

5. Stated Preference Techniques

A second class of techniques that can be used to estimate non-market values are those based on the stated preferences of individuals. Stated preference techniques involve the use of surveys from which estimates are derived of the non-market benefits of different resource use alternatives.

Because they rely on the use of surveys, stated preference techniques can be used in more applications than revealed preference techniques. For example, they are the only approaches that can be used to estimate non-use values. Consequently, stated preference techniques are needed for estimating many of the non-market values associated with bushfire prevention (e.g. changes in environmental quality, reduced risk of damage to critical infrastructure, value of warnings).

The two main stated preference techniques are contingent valuation and choice modelling, described in this section.

Contingent Valuation

Prior to the development of choice modelling, contingent valuation was the most widely used stated preference technique for estimating non-market values. Contingent valuation involves the estimation of non-market values through directly questioning respondents about their willingness to pay for specific options. Contingent valuation has been used in a range of studies to value the benefits of fire management, such as fuel treatments to protect forest health, recreation, downstream water quality and wildlife (e.g. Loomis and Gonzales-Caban 1994, Fried et al. 1999, Loomis et al. 2005, Walker et al. 2007). It has also been used to value other items of relevance to fire management, such as social impacts (Lindberg and Johnson 1997, Berrens et al. 1998) and forecasts (Asgary et al. 2007).

The basic idea of contingent valuation is that respondents are presented with a description of a change (e.g. undertaking measures to reduce fire risk in a national park), and a question is asked to identify their willingness to pay for this change. The basic idea is relatively straightforward, but in practice, there are many features that are critical in the design of a contingent valuation survey.

While it has a relatively long history, the contingent valuation method has also been a fairly controversial technique. This partly reflects its politicisation due to its usage in several high-profile cases, including valuing impacts associated with the Exxon-Valdez oil spill and mining in the Kakadu Conservation Zone in the Northern Territory. It also reflects the fact that the technique is prone to various biases. Owing to the Exxon-Valdez controversy, there has been a fairly acrimonious debate within the economic literature regarding its merits (e.g.

Diamond and Hausman 1994, Hanemann 1994). In the USA, contingent valuation was subject to a review by a panel of experts set up by the National Oceanic and Atmospheric Administration (NOAA) and chaired by two Nobel Prize winners, Ken Arrow and Robert Solow, to assess the appropriateness of its use in damage assessment (Arrow et al. 1993). The panel concluded that contingent valuation provided a useful starting point for damage assessment and provided a number of recommendations regarding the design of contingent valuation studies. Subsequently, contingent valuation has continued to be used in the USA as well as in other countries such as the UK.

In contrast, in Australia, policy-makers have been cautious about using contingent valuation after it was used for the Kakadu study and a study by the Resource Assessment Commission valuing forests in South-Eastern Australia (Bennett and Carter 1993, Bennett 1996). Few contingent valuation studies have been undertaken in Australia since then (e.g. Bennett et al. 1998). This reluctance has continued despite the many developments in the contingent valuation literature that have increased understanding of how to effectively design questionnaires, as well as the development of demand-revealing approaches (such as the use of cheap talk, certainty scales or dissonance minimising approaches; see below) that have been demonstrated to eliminate yea-saying[6] (Morrison and Brown 2009). This reluctance to use contingent valuation largely explains the interest of both researchers and policymakers in the development of choice modelling, described next.

Nonetheless, contingent valuation does have its advantages. First, it is analytically much simpler. Second, if the goal of the study is to produce a single valuation estimate for a program, then it is more appropriate than choice modelling. Third, it is generally easier to use for valuing particularly complicated goods (choice modelling requires that goods be separated into attributes and that levels be assigned to each of these attributes; this is often quite difficult). Fourth, there is empirical evidence that suggests contingent valuation produces valuation estimates that are either equal to or more conservative those from choice modelling, which is interesting as perceived bias was one of the main reasons that contingent valuation was rejected in Australia (e.g. Magat et al. 1988, Hanley et al. 1998, Stevens et al. 2000, Mogas et al. 2006). Thus, there are a number of good reasons to consider using contingent valuation if it is appropriate for the valuation task at hand.

Steps in Conducting a Contingent Valuation Study

Undertaking a contingent valuation study requires the following series of steps. For the interested reader, these are described in greater detail in Boyle (2003).

- **Identify the changes in quantity or quality to be valued**

[6] Yea-saying occurs when respondents indicate that they are willing to support a hypothetical referendum, but if the referendum involved an actual payment, they would not be willing to support the referendum.

The first step in designing a contingent valuation study is identifying the changes in quantity or quality to be valued that will be the subject of the valuation scenario. All relevant background information must be collected so that the good to be valued and the change occurring can be fully and reasonably described to respondents.

- **Identify whose values are to be estimated: household vs individual values**

The second step is to identify whose values are to be estimated. Most contingent valuation studies derive either per-person or per-household estimates, with the appropriateness of the choice depending on the context of the study. For example, for a study of recreational fishing value, a per-person value would generally be estimated. However, most studies estimating existence values generally derive values on a per-household basis (Mitchell and Carson 1989). The challenge is to be clear both when developing the survey instrument and aggregating values about whether individual or household values are being estimated. The estimation of household values also has important implications for sampling, and when estimating existence values, the appropriate procedure is to sample those involved in household decision-making.

- **Sampling**

The third step is to select a sampling procedure, as the method of sampling will influence the design of the questionnaire. A range of sampling procedures has previously been used, including mail, telephone, drop-off and pick-up, in person, internet and various hybrids. These procedures differ in their response rates, time required, cost, amount of information that can be conveyed and susceptibility to social desirability bias as well as sample frames. The sampling procedures used can affect value estimates (Boyle 2003). Most of these approaches are acceptable, though telephone surveys are limited in terms of the amount of information that can be communicated and hence tend only to be viable with goods that respondents are familiar with (Mitchell and Carson 1989). The accessibility and low cost of using internet panels has greatly increased interest in their use, and there is some evidence that these can produce valid responses (e.g. Li et al. 2004, Olsen 2009). However, a couple of studies (Van der Heide et al 2008 and Hatton MacDonald et al 2010) have reported evidence that sampling using internet panels produces value estimates that are lower than other sampling approaches, while other studies indicate that the way that the internet panel has been recruited influences its representativeness (Malhotra and Krosnick 2007).

- **Questionnaire design**

The fourth step is to design the questionnaire. Broadly, the challenge when developing the questionnaire is to carefully explain to respondents what they are being asked to value, how the good will be provided and how it will be paid for. There are also several other design features that must be included to ensure that accurate value estimates are derived.

Description of the good to be valued: as already noted, the change in the good being valued must be fully described to respondents, but in a way that is comprehensible to them. This generally means that only the key aspects of the changes can be described. For most studies this requires the collection of ecological information and the cooperation of both ecologists and biophysical scientists. In some cases, describing the good to be valued can be particularly challenging, particularly when there are changes in the probability of an event occurring. This is quite common in the case of bushfire prevention, and requires the use of approaches for communicating changes in risk (e.g. Fried et al. 1999).

Explanation of the method of provision: this describes how the change described in the valuation scenario will be achieved, which important for two reasons. First, value estimates have been demonstrated to depend on the method of provision (Johnston and Duke 2007). Second, it is important that the method of provision is seen to be credible, as this will influence the realism and the consequentiality of the survey instrument. Previous research has demonstrated that if respondents consider that a survey will have a limited or indirect effect on outcomes, they may simply indicate their general attitudes towards an object and ignore the costs involved. Empirical evidence has also demonstrated that if respondents do not consider that a survey is consequential, this can lead to higher value estimates (Bulte et al. 2005).

Selection of a payment vehicle: the payment vehicle is the method by which payment will occur. In practice, a range of vehicles is used, such as levies on water rates, income tax, electricity rates, payments into trust funds and general increases in prices (Boyle 2003). There is evidence that payment vehicles significantly affect value estimates (e.g. Morrison et al. 2000); however, there is no ideal payment vehicle. As Mitchell and Carson (1989) have noted, choosing a payment vehicle involves balancing realism and the possibility of payment vehicle rejection. It is desirable for all contingent valuation studies that payment vehicles be realistic so that households genuinely consider the costs of supporting a proposed change. For this reason, many studies choose payment vehicles such as water rates and income taxes. However, as taxes become more realistic, they are also more likely to produce protests; for example, if water rates or income taxes are already seen to be too high or if there are problems with limited coverage (eg not all households pay water rates), there can be protests against such payment vehicles. In summary, the goal in selecting a payment vehicle is to choose a vehicle that is realistic, has as wide coverage as possible, and induces a minimum number of protests.

Selection of a time schedule for payment(s): examples of the payment time frame include one-off, monthly, annual, and annual payments for a fixed number of years (e.g. five or ten years). Empirical studies (e.g. Stevens et al. 1997) have demonstrated that one-off payments produced statistically different estimates to repeat payments, and that implied discount rates[7] are very high[8]. The implication is that having a longer time schedule for payment will produce much larger valuation estimates than having a one-off payment schedule. The latter may thus appear to be the most conservative option, but it may not be realistic to expect households to pay for all of the change in an environmental good in a single year. Thus there is also a rationale for having longer time schedules for payment. This is generally an under-researched area in contingent valuation as well as choice modelling (see Boyle 2003). For larger projects, and where the costs of implementation will occur over multiple years, it would appear to be appropriate to use longer time schedules for payment.

Providing reminders of budget constraints and substitutes: one of the recommendations of the NOAA panel is to include strong reminders of budget constraints and substitute expenditure options prior to asking the valuation question. Various studies have demonstrated that excluding these reminders leads to higher estimates of willingness to pay (e.g. Whitehead and Blomquist 1995, Smith et al. 2005).

Selection of a response format: within the contingent valuation literature, a variety of response formats have been used to identify respondents' willingness to pay. One of the earliest approaches was open-ended questions, where respondents are asked 'What is the highest amount you would pay for program X?' Another approach is the use of payment cards (see Table 6), where respondents circle the highest amount they would be prepared to pay from a list of payment amounts. A third commonly used approach is dichotomous choice questions framed as referendum votes (see Table 7) in which the sample is split into sub-samples, each with a different cost or bid. For each sub-sample, the percentage of people voting in favour is calculated, and these data are used to calculate mean willingness to pay. Other approaches such as double-bounded and multiple-bounded response formats have also been used (see Boyle 2003).

Theoretically, the referendum format has the best properties and is the approach recommended by the NOAA panel (Arrow et al. 1993). However, this approach tends to be more susceptible to yea-saying than either the open-ended or payment card formats, but the other two approaches also have issues. As Boyle (2003) discusses, with the open-ended format, there tend to be excess zero bids, and with payment cards (and the referendum format) anchoring can occur whereby respondents base their willingness to pay on the bid levels provided to them in the questionnaire.

So how does one choose between the formats? Welsh and Poe (1998) compared four different formats and found that open-ended and payment card formats produced

[7] A discount rate is used to convert a stream of future payments to an equivalent current payment.

[8] This might appear to cast doubt on the validity of contingent valuation; however, there is ample market evidence that indicates that many people have particularly high discount rates in a variety of contexts. Furthermore, evidence suggests that the discount rates used by respondents appear to be a function of a variety of socio-demographic characteristics.

equivalent and lower estimates than the dichotomous choice formats, suggesting that these approaches are more conservative and should be favoured. However, their theoretical properties are weaker than those of the referendum format, and new demand-revealing techniques have now been developed that enable the referendum format to produce more conservative estimates. Thus, provided that one of these new techniques is utilised, the referendum format remains a viable option.

Table 6: The payment card contingent valuation format

If the passage of the proposal would cost you these amounts every year for the foreseeable future, what is the highest amount you would pay and still vote for the program? *Circle the highest amount at which you would still vote for the program.*
10c 50c $1 $5 $10 $20 $30 $40
$50 $75 $100 $150 $200 More than $200
Source: Welsh and Poe (1998)

Table 7: The referendum contingent valuation format

Would you vote in favour of the proposal to improve water quality at a cost of $50 per household, or would you vote against the proposal? *Tick one box only*
I would vote in favour of the proposal at a cost of $50 ☐
I would vote against the proposal at a cost of $50 ☐

Selection of a bid vector: for both the referendum and payment card formats, a bid vector must be developed. This is a list of the costs that is shown to respondents. A significant amount of literature is devoted to the optimal selection of bids for use with the referendum format (e.g. Alberini 1995, Kanninen 1995). Ideally, there should be a moderate number of bids (five to eight) and the bids should be clustered around the median and not in the tails of the distribution. In order to choose the approach bids, some information is needed about the distribution of bids prior to the main survey, which can be obtained through a pretest survey of 50 to 100 observations.

Including an approach for reducing yea-saying: it is well recognised that respondents tend to overstate their willingness to pay. Various meta-analyses have sought to identify the extent of this phenomenon. Little and Berrens (2004) took ratios of the amount respondents said that they were willing to pay versus the amount respondents actually paid from 42 studies; the average ratio was 3.13.[9] Murphy et al. (2005) reported several summaries of ratios; the summary most similar in methodology to that of Little and Berrens produced a mean ratio of 3.26 (with a median of 1.50).

There have been various attempts in the environmental economics literature to produce approaches that reduce this divergence between hypothetical and actual willingness to pay. These demand-revealing approaches include 'cheap talk' (e.g. Cummings and Taylor 1999), the use of 'certainty scales', and 'dissonance-minimisation' (Blamey et al. 1999).

Cheap talk involves use of an entreaty that identifies the issue of hypothetical bias to the respondents and urges them to answer accurately prior to presenting the valuation question. There has been a lot of interest in using cheap talk in the valuation literature, but it varies in its effectiveness. Nonetheless, it is most effective when the script presents a compelling case for avoiding hypothetical bias, for public goods where respondents are relatively inexperienced with the good being valued, and for moderate to high bid levels – all contexts where hypothetical bias is likely to be greatest. The only evidence from Australia about the use of the cheap talk script, by Morrison and Brown (2009), suggests that a full script over-corrected yea-saying, but a shorter and more moderate script may produce more accurate valuation estimates. Two examples of short cheap talk scripts are shown in Table 8.

Table 8: Example of short cheap talk scripts

[9] Little and Berrens (2004) updated and extended the meta-analysis of List and Gallet (2001). Most of the 42 studies Little and Berrens examined reported more than one ratio. To avoid over-emphasizing a given study, the authors compiled the median ratio for each study and then computed the mean across the 42 medians. Note that a few of the ratios were for willingness to accept compensation rather than willingness to pay.

Script 1: List et al. (2006)

In most questions of this kind, folks seem to have a hard time doing this. They act differently in a hypothetical situation, where they don't really have to pay money, than they do in a real situation, where they really have to pay money. We call this 'hypothetical bias'. 'Hypothetical bias' is the difference that we continually see in the way people respond to hypothetical situations as compared to real situations. So, if I was in your shoes, and I was asked to make a choice, I would think about how I feel about spending my money this way. When I got ready to choose, I would ask myself: if this was a real situation, do I really want to spend my money this way?

Script 2: Olar et al. (2007)

PLEASE NOTE:

We know that how people vote on a survey is often not a reliable indication of how people would actually vote at the polls. In surveys, some people ignore the monetary and other sacrifices they would really have to make if their vote won a majority and became law. We call this hypothetical bias. In surveys that ask people if they would pay more for certain services, research has found that people may say that they would pay 50% more than they actually will in real transactions.

It is very important that you 'vote' as if this were a real vote. You need to imagine that you actually have to dig into your household budget and pay the additional costs.

The second approach involves the use of follow-up certainty scales. Certainty scales are asked directly after the elicitation question, and allow respondents to indicate how sure they are that they would actually pay the amount, or vote, as they just indicated. Only respondents with a high certainty are then treated as actually being willing to pay. There are two basic versions of this approach. The first uses a numerical scale with labelled end-points. For example, Champ et al. (1997) used a 10-point rating scale with 1 labelled 'very uncertain' and 10 labelled 'very certain'. The other version offers two or more discrete options, each describing a level of certainty. For example, Blumenschein et al. (1998) used a two-category qualitative scale that allowed respondents to indicate whether they were 'probably sure' or 'definitely sure' about their prior response. With the numerical ratings scale, studies have found that those who give a rating of about 7 or 8 are those who are genuinely willing to pay (e.g. Ethier et al. 2000, Champ and Bishop 2001, Poe et al. 2002, Norwood 2005, Morrison and Brown 2009), and that recoding those with lower ratings as voting against the proposal leads to the elimination of the divergence between actual and hypothetical willingness to pay. There is a lot of evidence that this latter approach is quite effective. The challenge is knowing *a priori* what the appropriate cut-off should be; there is increasing literature suggesting that it is most commonly about 7 or 8, although it may differ across contexts.

The third approach to reducing yea-saying is known as the dissonance minimising approach. Respondents are presented with response categories beyond simple yes and no responses. First used by Blamey et al. (1999) (who named the technique) and Loomis et al. (1999), this approach is based on the view that hypothetical bias or yea-saying results from cognitive dissonance, which is an 'emotional state set up when two simultaneously held attitudes or cognitions are inconsistent or when there is a conflict between belief and overt behaviour' (Reber 1985, p. 129). As suggested by Brown et al. (1996), the standard dichotomous choice contingent valuation format may place respondents in the awkward position of choosing between two competing objectives: honestly responding to the bid level, and indicating whether or not they favour provision of the good. Respondents who favour the good but suspect that they would not pay as much as asked must choose which objective to pursue, and may choose the latter. The dissonance minimising (DM) format includes response categories that permit respondents to express support for a program without having to vote in favour of increased expenditure. For example, in the study of Blamey et al. (1999), the extra response categories included 'I support the [program] … but it's not worth $50 to me', 'I support the [program] … but I cannot afford $50', and 'I support the [program] but not if it requires a [fee] of any amount'. By decoupling the choice of whether to support the environmental program from the commitment of dollars, this questioning format attempts to reduce dissonance and hypothetical bias. The potential advantages of this approach are that, compared with certainty scales, one does not have to know *a priori* what the appropriate cut-off is and, furthermore, it is much easier to use than a longer cheap talk script. This approach has had limited empirical testing compared with cheap talk or certainty scales, but Morrison and Brown (2009) found in the Australian context that DM was equally effective to certainty scales in reducing yea-saying, and that both were better than using a full cheap talk script, which over-corrected yea-saying.

Developing auxiliary questions: the next step in designing a contingent valuation questionnaire is to develop auxiliary questions of several types. First, questions need to be included to identify protest votes. Some people may value the good but may protest against certain aspects of the scenario, such as the payment vehicle (Morrison et al. 2000). Other respondents may not understand the task that they are completing, and for this reason the NOAA panel advocated including a 'not sure' option when asking the valuation question. Boyle (2003) recommends at a minimum including questions to identify protest votes, while the NOAA panel recommend questions to understand why respondents voted yes or no (Arrow et al. 1993). Questions are also needed to establish construct validity, which is demonstrated when willingness to pay values are influenced by key socio-demographic characteristics such as income and age, and attitudinal variables. The NOAA panel recommend including questions to help interpret the response to the primary valuation question, such as questions about income, prior knowledge of the site, prior interest in the site, attitudes towards the environment, attitudes towards big business, distance to the site, understanding of the task, belief in the scenario and ability to perform the task.

- **Pretesting**

After the questionnaire design for a contingent valuation survey has been completed, the next step is pretesting of the instrument. This is generally done through the use of focus groups (generally four to seven) or in-depth interviews (about 20); pilot surveys are also typically conducted as a final check on the validity of the instrument. Questions that are asked when pretesting include:

- ✓ What was your impression of the questionnaire?
- ✓ Was there anything you didn't understand?
- ✓ Was there anything that you found confusing?
- ✓ Was there anything that you found hard to answer?
- ✓ Was there anything you didn't like or objected to?
- ✓ Was there anything you found biased?
- ✓ Was there anything that you skipped over?
- ✓ Was there anything that needed a fuller explanation?
- ✓ How did you answer the valuation question, and why?

When pretesting, attention not only should be given to written words, but also to any photographs that appear in the questionnaire because of the possibility of unforeseen bias; the NOAA panel recommended that photos be carefully explored for this reason (Arrow et al. 1993). With in-depth interviews, a procedure of verbal protocols, which involves asking those interviewed to verbalise their thoughts as they are answering the questionnaire, is sometimes used to assist with providing insight into the questionnaire.

- **Data analysis**

After pretesting has been completed and the survey data have been collected, data are analysed using procedures that depend on the elicitation format selected. For payment card formats, interval regressions are used, which can be estimated in statistical packages such as STATA. For referendum format contingent valuation, data are analysed using binary logit or binary probit models. The binary logit model has the following form, where P is the probability of choice:

$$\ln(P/1 - P) = \beta_0 + \beta_1 X_1 + \ldots + \beta_n X_n$$

Binary logit models can be estimated using relatively straightforward statistical packages such as SPSS, or more complicated statistical packages such as LIMDEP or STATA. An excellent reference on the statistical procedures required is Haab and McConnell (2002).

- **Estimation of willingness to pay and confidence intervals**

Once the statistical analysis has been completed, the modelling results can be used to estimate willingness to pay. For a linear random utility model, mean willingness to pay (WTP) is calculated using the following formula:

$$\mathrm{WTP}_j = \frac{\alpha z_j}{\beta}$$

where z_j is a vector of characteristics related to individual *j*, α is vector of model parameters and β is the coefficient for the cost parameter.

Confidence intervals for the WTP estimate are calculated using bootstrapping procedures. The most common approach used is the Krinsky–Robb procedure (Park et al. 1991). An explanation of how to operationalise this procedure is given in Haab and McConnell (2002).

In addition, lower bound estimates of willingness to pay[10] can also be estimated using non-parametric procedures such as the Turnbull estimator (Haab and McConnell 2002), which allows estimation of willingness to pay from raw data, without a regression model. The advantage is that this removes the need to estimate a regression model, but no insight is provided into how covariates such as socio-demographic characteristics influence willingness to pay. The steps required to use the Turnbull estimator are simply described in Haab and McConnell (2002, pp. 59–78).

EXAMPLE: Winter and Fried (2001)

Winter and Fried (2001) used open-ended contingent valuation to estimate the value of reducing the risk of bushfires for households located in a jack-pine forest in Michigan. Recent bushfires in the area had destroyed 70 homes. An in-person survey was conducted. The individual risk to each household was first objectively determined by experts and communicated to respondents through the use of risk cards[11]. Respondents were then asked about their willingness to pay for a risk reduction from their current level of risk through the use of 'public prevention and suppression programs'. The payment vehicle in the study was an increase in the annual property tax.

[10] Confidence intervals can also be straightforwardly calculated for willingness to pay estimated using the Turnbull estimator.

[11] The risk card used had 400 squares, and various numbers were shaded to illustrate different risk levels.

The risk that a respondent's home would be destroyed was calculated as (1) the probability that a wildfire would occur in the neighbourhood over the next 10 years (μ), and (2) the expert-assessed conditional probability that the respondent's house would be destroyed if such a fire occurred (ρ) (which depended on the fire prevention measures undertaken). The risk of fire occurring in the region was calculated to be 15%. Hence, depending on what actions had been taken, the joint or final probability that a house would burn down could be calculated as shown in Table 9.

Table 9: Estimating the joint probability of a house being destroyed based on management actions undertaken

Action taken	Conditional probability μ (1)	Conditional probability ρ (2)	Joint probability (μ * ρ)
1. None	0.15	0.93	0.14
2. Trees cleared	0.15	0.67	0.10
3. 2 + grass mowed	0.15	0.47	0.07
4. 3 + debris free	0.15	0.27	0.04

Some 407 residents were interviewed, producing a data set of 285 useable responses. Because of the large number of respondents indicating a zero willingness to pay (25%) (which is common with open-ended contingent valuation), the authors estimated what is known as a Cragg model (a generalisation of a Tobit[12] model that includes a probit [13] market participation model). The model estimates the probability of having positive willingness to pay and has a Tobit model component for those responses. Using this model, mean annual willingness to pay was estimated to be $57.26 (in 1994 US$). Willingness to pay was found to be influenced by several variables, including the initial risk assessment, with willingness to pay increasing by $21.75 for every 1% increase in initial risk above the mean, and property prices, with willingness to pay increasing by $7.51 for every $1000 increase in property prices.

[12] A Tobit model is similar to an ordinary least squares regression; however, it has the feature of allowing censoring. That is, one can specify thresholds in the model such that a dependent value takes on particular values below or above certain points. In this context, it allows the specification of a minimum willingness to pay of $0.

[13] A probit model has a zero or one dependent variable and is used to predict choice as a function of a vector of independent variables.

Choice Modelling

Over the past 15 years, choice modelling has increasingly been used for non-market valuation, and is now more common that contingent valuation. The two approaches share many similarities: they are both survey-based methodologies, and many of the design features of a contingent valuation questionnaire are required for a choice modelling questionnaire (e.g. scenario description, payment vehicle, time schedule for payment, auxiliary questions). The main differences between them relate to how goods are described, and in the way valuation questions are asked.

In contrast to contingent valuation, where respondents value single scenarios (such as a fire management program in a national park), choice modelling is what is described as a multi-attribute technique. That is, goods are decomposed into their constituent attributes:

$$X = (x_1, x_2, \ldots, x_n)$$

where X is the good and $(x_1, x_2, \ldots, x_n)$ are the attributes of the good.

As an example, forest recreation might consist of amenity quality, abundance of wildlife, availability of cabins, showers and toilets, camping areas, congestion and entry fees. Rather than value single scenarios, respondents evaluate multiple scenarios that have different features or attributes. An example of a choice modelling question developed to value the attributes associated with moose hunting is shown in Table 10.

Table 10: Example of a choice modelling question from Adamowicz et al. (1997)

1. Assuming that the following areas were the **ONLY** areas available, which one would you choose on your next hunting trip, if either?

Features of Hunting Area	**Site A**	**Site B**	
Distance from home to hunting area	50 kilometres	50 kilometres	Neither Site A nor Site B I will NOT go moose hunting
Quality of road from home to hunting area	Mostly gravel or dirt, some paved	Mostly paved, some gravel or dirt	
Access within hunting area	Newer trails, cutlines or seismic lines, passable with a 2WD vehicle	Newer trails, cutlines or seismic lines passable with a 4WD truck	
Encounters with other hunters	No hunters, other than those in my hunting party, are encountered	Other hunters, on ATVs, are encountered	
Forestry activity	Some evidence of recent logging found in the area	No evidence of logging	
Moose population	Evidence of less than 1 moose per day	Evidence of less than 1 moose per day	
Check ONE and only one box	☐	☐	☐

The advantage of undertaking evaluations of this kind and decomposing a good into its attributes is that estimates of value can be derived for each of the attributes that make up a good; in the above example, these are how much people are willing to pay for increased moose population or better access to a hunting area. This level of information about the value of attributes is often very useful for public policy.

Choice modelling has frequently been used to estimate recreation and non-use values associated with forestry resources (e.g. Adamowicz et al. 1994, 1997, Mogas et al. 2006). A couple of studies have sought to value fire management, although it was only one attribute among several relating to forest management (e.g. Bonnieux et al. 2006, Concu 2007). While choice modelling has seldom been used directly for valuing the benefits associated with fire management, other studies have produced values of relevance to fire prevention, such as valuing improved quality of supply (e.g. reduced outages) for water and electricity for both households and businesses (e.g. Goett et al. 2000, Hatton MacDonald et al. 2005, Hensher et al. 2005b, Morrison and Nalder 2009). Choice modelling has also been used to estimate the value of preserving jobs in rural areas (e.g. Morrison, Bennett and Blamey 1999).

How choice modelling works

So how does choice modelling work? How does it produce these values? In any market when consumers evaluate products they generally consider the features of the products when making their choices. Imagine being at a car auction. If a certain car was not as old, had a better safety rating, had better fuel economy and had better audio equipment one might expect that people would be willing to pay more for it and at a lower price it would be more likely to be chosen. Furthermore, if you attended the auction for several days, you'd probably start to get a pretty good sense of how much people are prepared to pay for the various features associated with cars, such as having additional air bags, better fuel economy, being a newer model car and so on.

This is similar to how choice modelling works. Respondents are asked to make a series of choices between several different goods that are defined using a common set of attributes. For each good the attributes are set at different levels. So each of the goods will have different prices, different facilities available, different levels of environmental quality etc. Respondents are then asked to choose their preferred alternative from each set of alternatives. The levels of the attributes will then be changed (eg some goods will be more expensive, others will be cheaper) and respondents will be asked to choose again. This process will be repeated until it is possible to identify how respondents are trading-off between the attributes of the good, and how much they are willing to pay for each attribute.

Advantages and disadvantages of choice modelling

The main advantage of choice modelling over contingent valuation is that it provides much greater information about people's values. Estimates of value (which are known as implicit prices) can be found for each of the attributes included in an alternative. This contrasts with contingent valuation where values are estimated only for a single scenario. In practice this means that with choice modelling it is possible to value multiple scenarios. Choice modelling is also particularly suited to benefit transfer, which is the reuse of valuation estimates at different sites (Morrison and Bergland 2006). This is because choice modelling focuses on the valuation of attributes, and attribute values can be more reasonably transferred between contexts than entire valuation scenarios. A third advantage of choice modelling is that it has much greater acceptance in Australia than contingent valuation. This is largely because choice modelling was seen to be less prone to bias than contingent valuation, However, as discussed in the section on contingent valuation, empirical evidence suggests that this is not the case, and hence one must also be mindful of the need to minimise yea-saying when designing choice modelling questionnaires.

Apart from the greater potential for yea-saying, the main disadvantage of choice modelling is complexity. It is more challenging to develop a choice modelling than a contingent valuation questionnaire. In particular, it can be challenging to break a scenario or good into product attributes and select appropriate levels for these attributes. Secondly, the development of the choice questions requires the development of an experimental design (described shortly), and thirdly, the statistical analysis is more complicated.

Steps in undertaking a choice modelling study

The steps in undertaking a choice modelling study are described below; references providing excellent overviews of the choice modelling approach include Hensher et al. (2005a), Bennett and Blamey (2001), Holmes and Adamowicz (2003) and Kanninen (2007).

- **Identify attributes**

The first step is to define the good of interest in terms of its attributes. For some goods (e.g. recreational value), this might be fairly straightforward, but for other goods (e.g. estimation of existence values), determining the attributes is more difficult. There are two main ways. The first is to ask experts in the area; the second, and arguably the best way, is to ask the potential respondents how they make their choices. Normally one would include between four and eight attributes to describe a good in the context of non-market valuation. However, there is beauty in parsimony, and it is easier for respondents if there are fewer attributes. It is also preferable to include attributes that are naturally uncorrelated if possible – that is, that can vary independently of each other. However, if attributes are correlated, it is possible to allow for these correlations through the use of 'nested' experimental designs.

- **Define attribute levels**

Once the attributes have been selected, their levels or values have to be defined. Generally this is a more difficult task than selecting attributes. For each attribute, between two and five levels need to be selected, though it is a good idea from an experimental design perspective if each attribute has a similar number of levels (see next step). For example, the attribute price might have four different levels: $2, $5, $7 and $10. When selecting the attribute levels, the range should be as large as possible, without being implausible. Empirical studies have demonstrated that reducing the variability (the attribute range) in the levels of more important attributes can increase the importance of less important attributes (e.g. Meyer and Eagle 1982). Attribute levels can be quantitative or qualitative.

- **Develop alternatives**

In the next step, the alternatives that respondents evaluate are developed by systematically combining attributes using an experimental design.

All possible alternatives derived from a set of attributes are known as the full factorial. For example, if one is seeking to understand respondents' willingness to pay for camping facilities, two attributes (say price and camping facilities) that have two levels can be combined to form four alternatives. Using a design catalogue or statistical program (e.g. SPSS) generates the results shown in the first two columns marked X_1 and X_2 below. The experimental design is then converted into alternatives in the following way.

	X_1	X_2		X_1	X_2
Alternative 1	0	0		\$10	no facilities
Alternative 2	0	1	==>	\$10	facilities
Alternative 3	1	0		\$20	no facilities
Alternative 4	1	1		\$20	facilities

However, as the number of attributes and the number of attribute levels increase, the number of alternatives in the full factorial increases exponentially:

Two attributes with two levels = 2^2 = 4 alternatives

Two attributes with three levels = 3^2 = 9 alternatives

Four attributes with three levels = 3^4 = 81 alternatives

Six attributes with three levels = 3^6 = 729 alternatives

In practice, it is not possible to use all of the full factorial, so we make use of fractional factorials, which is a sample of the alternatives from the full factorial. Fractional factorials may have useful properties like orthogonality, which means that the attributes are not correlated, a helpful feature for reducing multicollinearity in regression analysis. A second property is balance, which means that each level of an attribute is combined with the levels of each other attribute an equal number of times. Because not all the alternatives are included, fractional factorials allow one to estimate 'main effects' but not all interactions between attributes. A main effect is the direct contribution of an attribute to the utility of a good. A two-way interaction occurs when the contribution of an attribute to the utility of a good depends on the *level of one of the other attributes.* For example, the contribution of power steering to utility may depend on the engine size of the car. Mathematically, mains effects and two-way interactions can be expressed as follows:

$$Y = \beta_1 \cdot X_1 + \beta_2 \cdot X_2 + \beta_3 \cdot X_1 \cdot X_2$$

where Y is the dependent variable, X_1 and X_2 are the mains effect for attributes 1 and 2, $X_1 \cdot X_2$ is a two-way interaction, and β_1, β_2 and β_3 are regression coefficients.

If, in an estimated a regression model, β_3 is statistically significant, there is a significant two-way interaction. Louviere (1988) reports that:

- main effects typically explain 80% or more of the variation in response data
- two-way interactions typically explain 3–6% of the variation
- three-way interactions typically explain 0.5–1% of the variation.

In most choice modelling applications focused on non-market valuation, it is assumed that two-way and higher-order interactions are insignificant, and for simplicity, only main effects are estimated.

So far in this discussion of experimental design, the development of alternatives has been considered. There are typically two or more alternatives as well as an opt-out or 'choose neither' alternative in choice modelling questions. How then are the alternatives chosen for the choice sets? This is done by: (1) the use of simultaneous designs, which is effectively a much larger fractional factorial where the alternatives and choice sets are created simultaneously; (2) sequential designs, where modular arithmetic is used to create the second (and third alternative) in every choice set; and (3) random assignment (Bunch et al. 1993, Louviere et al. 2000).

The different ways available to develop an experimental design beg the question of what is the best way. There has been much interest in the literature in how to maximise the efficiency of experimental design, and various measures of efficiency have been advocated, such as D efficiency(Scarpa and Rose 2008), with each measure assessing the amount of trade-off information produced by the experimental design. A design that is 100% efficient would have trade-offs on every attribute, so that there are no ties between them (a tie occurs when two alternatives have the same attribute level, e.g. they both cost the same amount). Although researchers think this is a good idea because it produces the maximum amount of trade-off information, in reality, such choice tasks are very difficult for respondents to answer, and while statistical efficiency is maximised, respondents tend to make a lot of mistakes, meaning that respondent efficiency is not maximised. Hence, some researchers have advocated using designs that do not have such high levels of efficiency (Severin 2001, Louviere 2004).

More recently, experimental designers have begun to use Bayesian procedures to assist in the development of experimental designs. Using prior information about the likely parameters of the final regression equation, they develop experimental designs that seek to minimise the variance–covariance matrix of the regression. Basically, this means that with some idea of the sign or magnitude of the model parameters, you can select a design that will assist in reducing model variance. Researchers will often conduct a small pilot study (say 50 respondents) for information to develop priors (i.e. expectations about the sign and magnitude of each of the model coefficients), but even basic information that can be guessed (e.g. the likely sign of a coefficient) is helpful in developing designs of this type. This is a substantial departure from the methods used to develop orthogonal designs just described. The goal with these 'efficient' designs, as they have become known, is to minimise model variance rather than the statistical efficiency of an experimental design[14]. The results from using these efficient designs have been promising (e.g. Scarpa and Rose 2008, Kerr and Sharp 2009), but some questions still remain, such as about the appropriateness of an efficient design for different model specifications (Kerr and Sharp 2009). Nonetheless, the use of these designs has the potential to substantially reduce sampling requirements and the costs of conducting a survey.

Thus, how should one go about developing an experimental design? This is one of the most delicate parts of choice modelling and easy to get wrong, so it is advisable to initially get assistance with developing an experimental design. Simple orthogonal designs are freely available in design catalogues or websites (e.g. Hahn and Shapiro 1966 or Sloane's library of 'orthogonal arrays' on the internet[15]) or through various statistical packages (e.g. SAS); professional experimental designers will also develop orthogonal designs with desirable properties. Efficient experimental designs are generally developed by experimental designers with expertise in Bayesian analysis as no statistical packages are currently available, but these are being developed and should be available within the next couple of years.

- **Block alternatives**

An experimental design will usually produce too many alternatives for each person to evaluate. Generally, only about four to eight choice modelling questions can be answered by each respondent and some means are therefore needed to divide the choice sets between respondents. This is called 'blocking'. Blocking can be carried out by (1) random assignment; (2) systematic assignment; and (3) creation of a blocking variable when developing the experimental design.

[14] Efficient designs do not have the orthogonality property of standard designs. However, as efficient designers point out, once levels are assigned to an orthogonal design, the orthogonality of these latter designs is removed. That is, they are only orthogonal in their raw form.

[15] http://www2.research.att.com/~njas/oadir/ (accessed 13/09/10)

- **Developing the questionnaire**

Once the experimental design has been developed and the choice sets divided into blocks, the questionnaire needs to be developed. As mentioned previously, choice modelling questionnaires require many of the features of contingent valuation questionnaires, including information about the scenario, the payment vehicle, the payment schedule, reminders about budget constraints and substitute expenditure options, an approach for reducing yea-saying and the inclusion of auxiliary questions. As these have already been discussed, they do not need to be reiterated here, and attention will be given to the design features unique to choice modelling questionnaires.

Defining of attributes and levels: the first distinguishing feature of a choice modelling questionnaire is that the attributes and levels used to define the good need to be introduced when presenting the valuation scenario. Typically, potential changes in the quality or quantity of the good are described in terms of these attributes (eg see Table 11). This provides a suitable context for identifying and defining the attributes and levels used. Sometimes information sheets are also included that define the attributes and levels for respondents to refer to when answering the questions.

Explanation for the choice modelling questions: prior to asking the questions, an explanation is needed for the respondents because without this, choice modelling questions are likely to be quite confusing. These introductions typically have the following features:

- ✓ Respondents are told that they will be asked several questions
- ✓ Respondents are told why they are being asked these questions: to identify the features that are important to them and what they are prepared to pay for
- ✓ Respondents are told that the features of the alternatives change across questions (this is something easily missed by respondents)
- ✓ The existence of alternatives that might seem odd or implausible is explained
- ✓ Respondents are reminded about budget constraints and alternative expenditure options

An example of such an introduction is shown in Table 11.

Table 11: Example of an introduction to the choice modelling questions

What do you think? We would like to know what you think about paying extra water rates to improve the quality of the Bega River. To do this we ask you to consider eleven different options that we have called **Options A to K**. Work on achieving these options would start at the beginning of next year and improvements in the river environment would be noticeable over the following two years. **Option A** is the current situation, which means that there is no levy on water rates and no new environmental projects. All of the other options involve a levy on water rates that is used to pay for additional environmental projects. **Different types and combinations of projects are funded under each option.** Because there are so many options, we ask you to consider only three at a time in Questions 6 to 10. From each set of options, choose your preferred option by looking at the **levy amount** and the **effects** the projects will have on the environment. Some of these outcomes may seem strange. However, remember that they depend on the combination of projects chosen.

Source: Morrison and Bennett (2004)

Design of the choice questions: the choice set is then designed. This requires a number of decisions, the first of which is whether to use a generic or labelled choice set. Generic designs are used most frequently for non-market valuation, whereas labelled experiments are more common in marketing studies. In generic designs, the heading for each alternative, apart from the status quo or 'choose neither' alternative, is a generic name such as 'Option A', 'Option B', which does not differentiate between these non-status quo alternatives. In contrast, with a labelled alternative, the headings do have meaning. For example, in marketing studies, the headings are commonly used to represent brands, or in environmental valuation studies, to represent particular locations or travel destinations. They can also be used to refer to a different kind of management style or a different level of environmental improvement. Examples of labelled and generic choice sets are shown in Table 12.

A second decision when designing choice sets is deciding how many alternatives to include. Previous studies have included from two to four alternatives, though most commonly there are three alternatives, one of which is the status quo. It is important from a theoretical perspective and strongly recommended in the literature that a 'choose neither' alternative be included, giving respondents the option to opt out from purchase, so that willingness to pay is only calculated using information from those who are actually prepared to pay. Theoretically, excluding the 'choose neither' option should lead to an upward bias in willingness to pay (Freeman 1991, Bennett and Blamey 2001), but the two studies that have empirically tested the effect of excluding the status quo alternative have not found it to affect values (Carlsson et al. 2007, Boyle and Ozdemir 2008). In terms of whether to have two or three alternatives (both including the status quo), Rolfe and Bennett (2008) found that using three alternatives was superior and produced more efficient estimates. Boyle, Morrison and Taylor (2004), however, produced contrary evidence. They argued that the two-alternative choice set design has better incentive properties and produced empirical evidence to support this position[16]. They included a referendum provision rule with a two-alternative choice modelling study (one alternative was the status quo) and found that this approach produced implicit prices equivalent to a treatment involving actual cash payments, while the three-alternative choice modelling treatment produced biased results. Thus, there is some contention in the literature about whether to include two or three alternatives, and the latter remains the most common approach.

A third decision to be made is where to position the attributes in a choice set, as changing the placement of attributes may affect attribute values. Some studies have found evidence of attribute-ordering effects (Acito 1977, Scott and Vick 1999, Kjaer et al. 2006). For example, Kjaer et al. (2006) found that value estimates were 42% lower when the price attribute was the last in the list rather than the first. However, other studies (e.g. Farrar and Ryan 1999, Boyle and Ozdemir 2008) have found no ordering effects. Hence, the evidence indicates that attribute ordering can, but does not always, matter.

[16] As noted by Carson and Groves (2007), a three-alternative choice set is not incentive-compatible. That is, it is not optimal for a respondent to state their true preferences when there is a choice between three alternatives. This is, however, not the case when there is a single binary referendum. Most choice modelling applications include multiple alternatives in a choice set, respondents answer several choice sets, there is no provision rule (e.g. a referendum) specified, and the consequentiality of participating in a survey may be unclear. Hence the incentive properties for truthful revelation can be quite weak. The challenge when developing a choice modelling questionnaire is to develop incentive properties that are as strong as possible.

Table 12: Labelled and generic choice sets

Labelled choice set design

Implications	Option A Current Guidelines Graziers to leave at least 20% of trees	Option B Graziers to leave at least 30% of trees	Option C Graziers to leave at least 50% of trees
Levy on your income tax	none	$20	$100
Income lost to the region ($ million)	none	9	11
Jobs lost in region	none	18	30
Number of endangered species lost to region	18	16	10
Reduction in population size of non-threatened species	80%	70%	40%

Generic choice set design

Implications	Option A Current Guidelines	Option B	Option C
Levy on your income tax	none	$60	$20
Income lost to the region ($ million)	none	5	10
Jobs lost in region	none	15	40
Number of endangered species lost to region	18	8	4
Reduction in population size of non-threatened species	80%	75%	45%

Source: Blamey et al. (2002)

- **Pretesting**

As with contingent valuation, once the questionnaire has been developed, the next step is pretesting, which is usually done through the use of focus groups and in-depth interviews. Particular attention is given to whether respondents understand the attributes and levels, and are able to meaningfully answer the choice modelling questions. It is commonplace when pretesting to ask respondents how they went about answering the choice modelling questions to ensure that the methodology they used is consistent with theory. As noted in the experimental design section, a pilot survey can be conducted to produce data for developing the final experimental design if an efficient design is being used.

- **Conducting the survey**

Once the questionnaire has been developed and pretested, the next step is sampling. There are fewer sampling options for choice modelling than continent valuation because of the additional complexity of choice modelling questionnaires. The questionnaires cannot be readily completed over the telephone but other forms of sampling such as mail, drop-off and pick-up, face-to-face and internet are common.

- **Data analysis**

The analysis of multinomial discrete choice data was discussed in the Random Utility Travel Cost Model section (see Section 4). The basic model for analysing discrete choice data with three or more alternatives is the conditional logit model (sometimes called the multinomial logit model).[17]

Researchers, however, have often used other models such as nested logit, multinomial probit and random parameters logit models, primarily because of concerns about bias due to the violations of the assumptions in the conditional logit model discussed previously (see footnote 4). While the existence of these violations can affect the ability of the model to accurately predict market share, theoretically they are unlikely to influence value estimates (Ruud 1983, 1986, Wooldridge 2002). In recent years, researchers have been particularly interested in using the random parameters logit model, which allows the researcher to specify distributions (e.g. normal, log-normal) for each of the model parameters and has the advantage of more fully modelling preference heterogeneity, that is, the distribution of preferences for different model parameters. While independence of irrelevant alternatives (IIA) violations should not be a motivation for using this model, those interested in more

[17] The logic behind this model is more fully explained in the section on the Random Utility Travel Cost Model.

fully modelling heterogeneity may be attracted to this model (Haab and McConnell 2002, Swait 2007).

- **Calculating values and confidence intervals**

Discrete choice models can be used to estimate implicit prices for attributes, which is the value of a unit change in an attribute. Implicit prices are calculated by dividing the coefficient from the regression equation of the attribute that you want to value by the coefficient for the monetary attribute. For example, for the case of the value of camping facilities, the implicit price would be calculated as follows:

$$\text{Implicit Price for the Presence of Camping facilities} = \beta_{\text{Camping Facilities}}/-\beta_{\text{Cost}}$$

This formula produces an estimate of value by allowing one to determine what change in cost has the same effect on utility as having camping facilities. Let's suppose that $\beta_{\text{Camping Facilities}} = 0.2$, and $\beta_{\text{Cost}} = -0.01$. This means that if there are camping facilities at a recreational site, utility is increased by 0.2. Cost has to increase by \$20 ($-0.01 \times 20 = -0.2$) to reduce utility by this same amount. Hence the implicit price for camping facilities is \$20, and can quickly be calculated by dividing $\beta_{\text{Camping Facilities}}$ (0.2) by β_{Cost} (–0.01).

Confidence intervals for most linear models (e.g. conditional logit, nested logit) can be calculated using the Krinsky–Robb procedure, as described in the section on contingent valuation above.

EXAMPLE: Concu (2007)

Concu (2007) developed a choice modelling study in consultation with the Kings Park management authority in Perth, Western Australia. Kings Park covers an area of about 400 hectares and is located on the fringe of the Perth business district. Three major management problems include weeds, trampling and fires. Concu (2007) developed a choice set with three attributes apart from price: % weed-free bushland (ranging from 30 to 60%), % bushland annually destroyed by fire (ranging from 1 to 9%), and % bushland accessible to the public (ranging from 25 to 100%). Management options to achieve improvements in these attributes included weed eradication, preventing fire and closing bushland to the public to reduce trampling. The payment vehicle was a contribution to income tax. A mail survey was conducted, yielding a sample of 324 responses (42% response rate) and the data were analysed using a conditional logit model. While Concu (2007) does not report value estimates for individual attributes, these can be inferred from the modelling results. The coefficient for fire management was not found to be significant, which implies that reducing fire risk is not valued by respondents. However, a number of interactions (with income and environmental attitude) were either significant or close to being significant, implying that certain groups within the population do value reducing fire risk. If the income and environmental attitude interactions are included, willingness to pay was about $1.17 per 1% reduction in fire risk.

6. Choosing Techniques for Estimating the Values Associated with Fire Management

In previous sections, the main approaches that can be used to value the benefits associated with fire management have been reviewed. The goal of the present section is to summarise which valuation approaches can be used for valuing each of these benefits (see Table 13).

Recreation is one of the easiest goods to value, and can be valued using any of the travel cost approaches, as well as contingent valuation or choice modelling. If the goal of the study is to understand how recreational value may change with recreational quality, the most appropriate approaches to use are the individual and zonal travel cost model, or choice modelling. There have been a range of travel cost studies examining how recreational values are affected by forest fires, including Englin et al. (2001), Loomis et al. (2001), Hesseln et al. (2003), Hesseln et al. (2004), although all of these were conducted in the USA.

Flora, fauna and invasive species are more difficult to value as they generally involve existence values. Estimating these values requires the use of contingent valuation or choice modelling because these are the only approaches capable of estimating existence values. Several US contingent valuation studies have examined the community's willingness to pay to protect endangered species from bushfires (e.g. Loomis et al. 1996, Loomis and Gonzalez-Caban 1998), and one Australian choice modelling study has estimated willingness to pay to protect bushland and reduce invasive species (Concu 2007). Several other Australian choice modelling studies have examined the community's willingness to pay for increasing fauna species and vegetation, though not in the context of bushfire prevention (e.g. Morrison, Bennett and Blamey 1999, Morrison and Bennett 2004).

Air, soil and water quality can be valued through market-based approaches, particularly where it is possible to link changes in quality to health (e.g. Glover and Jessup 1999, Butry et al. 2001) and other impacts, such as water treatment costs (Loomis et al. 2003). Air and water quality are also amenable to valuation through stated preference techniques such as contingent valuation and choice modelling. Changes in visibility have been valued using contingent valuation (e.g. Smith et al. 2005), while water quality has been valued using both contingent valuation (Johnston et al. 2003) and choice modelling (e.g. Morrison and Bennett 2004).

Cultural heritage can potentially be valued through both revealed and stated preference techniques. To the extent that cultural heritage sites generate recreation, travel cost approaches can be used to estimate recreation values and changes in these values due to bushfire. Where they also generate existence values, stated preference techniques can be applied. For example, Morey et al. (2002) have used stated preference studies to value prevention of damage to historic buildings and other cultural resources.

Social disruption, as noted in Table 1, has many facets. For some aspects of social disruption such as the loss of infrastructure (e.g. roads and schools), the hedonic price method may be used. For many other aspects, stated preference techniques are needed. For example, contingent valuation has been used to value changes in the risk of lost homes (e.g. Fried et al. 1999), warnings (e.g. Asgary et al. 2007) and road closures (e.g. Loomis et al. 2008). Choice modelling has been used to value water and power outages (e.g. Goett et al. 2000, Hatton MacDonald et al. 2005, Hensher et al. 2005b, Morrison and Nalder 2009) as well as the value of preserving jobs in rural areas (e.g. Morrison, Bennett and Blamey 1999).

Table 13: Suitable approaches for estimating the values associated with fire prevention

Value	**Potential valuation approaches**
Recreation	Travel cost models, contingent valuation, choice modelling
Flora, fauna and invasive species	Contingent valuation and choice modelling
Air quality	Market-based approaches, contingent valuation
Soil	Market-based approaches
Water quality	Market-based approaches, contingent valuation, choice modelling
Cultural heritage	Contingent valuation, choice modelling
Social disruption	Hedonic pricing, contingent valuation, choice modelling

7. A Summary of Existing Valuation Studies Relevant to Fire Management

In this section, studies relevant to the valuation of the benefits associated with fire management are summarised, categorised using the areas of benefit identified in Section 6. Note that more detailed summaries of many of these and other studies of relevance to fire management can be obtained from the EVRI (Environmental Valuation Reference Inventory) database (www.evri.ca), which Australian residents can currently subscribe to free, or the ENVALUE database, located on the NSW Department of Environment, Climate Change and Water's website (www.environment.nsw.gov.au/envalue); however, the latter database has not been updated for a number of years.

Recreation

Study	Location	Methodology	What was valued	Estimate
Bennett (1984)	NSW, Australia	Contingent valuation	Decrease in recreation value from fires in Ben Boyd, Morton and Kosciusko National Parks	Declines in recreational values per visit (1983 AU$): Ben Boyd $0.39, Morton $0.46, Kosciusko $0.90 (immediately after a large fire) Recreational values pre-fire: Ben Boyd $4.74, Morton $2.15, Kosciusko $4.67 (per visit)
Gonzalez-Caban et al. (2003)	San Bernardino National Forest, USA	Contingent valuation and Travel cost method	Willingness to pay for an additional deer harvested as a result of the use of prescribed burning	Travel cost method: US$257 per additional deer harvested Contingent valuation: US$222 per additional deer harvested Annual benefits from prescribed burning range from $3840 to $7920 for the first 1100 acres burned. For

				3710 additional acres burned, gain is $1910 per year, and an additional $960–1200 per year for a further 3710 acres burned.
Hesseln et al. (2003)	New Mexico, USA	Individual travel cost method	Effects of wild and prescribed bushfires on recreational values for hikers and mountain-bike riders.	Hikers – *prescribed fire* (years after fire/value per trip US$): 0 yrs/$130.24, 20 yrs/$74.19, 40 yrs/$51.87 Hikers – *crown fire* : 0 yrs/$90.29, 20 yrs/$98.09, 40 yrs/$107.35 Bike riders – *prescribed fire*: 0 yrs/$150.53, 20 yrs/$44.05, 40 yrs/$25.80 Bike riders – *crown fire* : 0 yrs/$9.66, 20 yrs/$8.24, 40 yrs/$7.19 Note: there were also effects on the number of trips not reported here
Hesseln et al. (2004)	Montana and Colorado, USA	Individual travel cost method	Effect of (1) prescribed and (2) crown fires on recreation values in National Forests.	*Prescribed fires* (years after fire/value per trip US$) Colorado: 0 yrs/$54.59, 20 yrs/$79.10, 40 yrs/$143.54 Montana: 0 yrs/$11.54, 20 yrs/$11.54, 40 yrs/$11.54 *Crown fires* Colorado: 0 yrs/$55.21, 20 yrs/$28.87, 40 yrs/$19.55 Montana: 0 yrs/$11.57, 20 yrs/$10.80, 40 yrs/$10.12 Note: there were also effects on the number of trips not reported here

Flora, fauna and invasive species

Study	Location	Methodology	What was valued	Estimate
Loomis and Gonzales-Caban (1994)	Oregon, USA	Contingent valuation	Willingness to pay to reduce fire hazard in an old-growth forest that provides important habitat for the Northern Spotted Owl, a threatened species. Fire hazard would be reduced by greater fire prevention, earlier fire detection and quicker and larger fire control response	Willingness to pay for a reduction by 50% from 7000 acres per year on average burned to 3500 acres per year burned is US$90 per household per year
Loomis et al. (1996)	Oregon, USA	Contingent valuation	Willingness to pay to reduce fire hazard in an old-growth forest that provides important habitat for the threatened Northern Spotted Owl	(US$ per household per year) *Without reminder about budget constraints and substitute expenditures:* open-ended $35.88, dichotomous choice $91.57 *With reminder about budget constraints and substitute expenditures:* open-ended CV $32.96, dichotomous choice CV $98.32
Riddel and Loomis (1998)	California and Oregon, USA	Contingent valuation	Non-use value of reducing fire hazard in California and Oregon's Spotted Owl habitat located in old-growth forest	Willingness to pay for the Oregon and combined (Californian and Oregon) program was US$3.38 and $3.93 per household per year respectively.
Loomis and Gonzales-Caban (1998)	California and Oregon, USA (sampling occurred in California as well	Contingent valuation	Non-use value of reducing fire hazard in California and Oregon's Spotted Owl habitat in old growth forests. This included the use of fire hazard reduction, early fire detection, increased	Willingness to pay per household for reducing acres burned by the sample average of 2,570 acres was US$56 per year

	as in various New England states)		fire protection and larger fire control response.	
Schechter et al. (1998)	Israel	Contingent valuation	Protection of Carmel National Park from fire equivalent to the magnitude of the 1989 fire	Willingness to pay for users and passive users were NIS54.7 and NIS46.5 respectively.
Loomis et al. (2005)	California, Florida and Montana, USA	Contingent valuation	25% reduction in the number of acres of wildfire in respondents' county and state through (1) an expanded prescribed burning program, and (2) a mechanical fire fuel reduction program	*Prescribed burning* (US$ per household per year): California $416.95, Florida $305.04, Montana $382.02 *Mechanical burning*: California $402.97, Florida $229.74, Montana $207.94
Gregory (2000)	Western Oregon, USA	Contingent valuation	Reductions in the average number of acres of critical habitat units burned in old-growth forests each year	75% reduction – US$41.38 (per household per year) 50% reduction – US$26.53 25% reduction – US$11.70
Bonnieux et al. (2006)	Corsica, France	Choice modelling	Fire prevention program for the forest of Bonifatu (3000 ha), which averages 25 ha per year burned	€39.5 to €47.2 for residents and €5 for visitors
Concu (2007)	Perth, Australia	Choice modelling	Willingness to pay for 1% reduction in risk of fire in King's Park, located on the fringe of the Perth business district	AU$1.17

Air quality

Study	Location	Methodology	What was valued	Estimate
de Mendonca et al. (2004)	Amazon rainforest, Brazil	Dose-response + benefit transfer	Morbidity resulting from smoke between 1996 and 1999 in the Brazilian Amazon	US$3.4-10.7 million
Rittmaster et al (2006)	Alberta, Canada	Various	Prediction of smoke dispersion and estimating the health-related economic impact associated with smoke plume (e.g. asthma, acute respiratory problems, cardiac admissions).	Total economic impact from one day of the fire was CA$10–12 million

Water quality

Study	Location	Methodology	What was valued	Estimate
Loomis et al. (2003)	Southern California, USA	Repair cost	Effect of using five-yearly prescribed burning (instead of bushfire, which occurs on average every 22 years) on sedimentation yield. Bushfires cause sediment build-up in public works sediment traps.	US$23.74 million per year
Hatton-MacDonald et al. (2005)	Adelaide, Australia	Choice modelling	Reduction in the number and duration of potable water-supply outages	Per outage: AU$6.00–15.40 Per hour reduction in duration (from 6 h): AU$1.10–4.40

Hensher et al. (2005b)	Canberra, Australia	Choice modelling	Willingness to pay for alternative frequencies and durations of potable water-supply outages	*Outages*: once in 10 years AU$113.20; once per year AU$62.26; twice a year AU$41.51; monthly AU$9.58 *Duration*: 1 hour AU$54.75; 2 hours AU$36.50; 5 hours AU$18.25; 8 hours $12.17; 12 hours AU$8.42; 24 hours AU$4.38

Cultural heritage

Study	Location	Methodology	What was valued	Estimate
Morey et al. (2002)	Washington DC, USA	Choice modelling	Benefits of reducing acid deposition injuries to 100 outdoor monuments. Respondents were shown photos of the likely damage to monuments in the future and asked about their willingness to pay to increase the amount of time before this damage occurs by 25, 50 and 100%	US$ per household, one-off payment 25% – $32.69 50% –$47.14 100% – $68.49
Allen Consulting Group (2005)	Australia	Choice Modelling	Willingness to pay for the *protection of additional heritage places from loss*	$5.53 (A$) per person each year for every 1000 places protected

Social disruption

Study	Location	Methodology	What was valued	Estimate
Fried, Winter and Gilless (1999)	Michigan, USA	Contingent valuation	Willingness to pay for the risk of respondents' homes being destroyed in a bushfire via a range of private and public risk reduction measures. Residents were located in a Michigan jack pine forest.	50% reduction in risk through private measures, from initial risk level (per household per year): 4% risk US$1390; 7% or 10% risk US$2364; 14% risk US$413 50% reduction in risk through public measures, from initial risk level (per household per year): 4% US$51; 7% US$61; 10% US$109; 14% US$92
Morrison et al. (1999)	NSW, Australia	Choice modelling	Willingness to pay (1) to preserve an additional rural job, (2) for an additional endangered and protected waterbird species to be present, (3) for an additional square km of vegetation (in the Macquarie Marshes)	AU$ per household, one-off payment (1) $0.13–0.14 per job (2) $4.04–4.16 per species (3) $0.04–0.05 per square kilometre
Winter and Fried (2001)	Michigan, USA	Contingent valuation	A 50% reduction in the risk of the respondents' homes being destroyed in a bushfire through collective risk reduction measures. Residents were located in a Michigan jack pine forest.	US$57.26 per year (for those with positive willingness to pay, which was 75% of respondents)
Loomis (2004)	Pine, Colorado, USA	Hedonic pricing	Reduction in property prices after a forest fire in the town of Pine, CO, after a fire in the nearby Pike-San Isabel National Forest which burned parts of the nearby town of Buffalo Creek (2 miles from Pine)	15–16% reduction in property prices in the 5 years after the fire
Kim and Wells	Flagstaff, Arizona,	Hedonic	Increase in property prices from fuel reduction treatments that convert high canopy closure to medium canopy closure	US$190 per 1000 m^2 per home

(2005)	USA	pricing	(note: canopy closure is the percent of a forest area occupied by the vertical projection of tree crowns and is a close approximation of stand density)	

Other

Study	Location	Methodology	What was valued	Estimate
Asgary et al. (2007)	Tehran, Iran	Contingent valuation	Willingness to pay for an earthquake early warning system	US$38 per month per household
Morrison and Nalder (2009)	NSW, Australia	Choice modelling	Willingness to pay of businesses to reduce: (1) blackouts, (2) length of blackouts and (3) brown-outs and surges	(1) AU$182.47 per blackout (2) AU$7.90 per minute (3) AU$84.22 per brown-out or surge
Willis and Garrod (1997)	UK	Contingent ranking	Willingness to accept compensation of households for (1) an additional outage per year and (2) an increase in the duration of outages	(1) 6.61–6.88% reduction in bill per outage (2) 0.05% reduction in bill per minute

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Appendix : Example of the Calculation of Market Share Using a Conditional Logit Model

An example of how to calculate market share using a conditional logit model is given below, using data from a stated preference (choice modelling) study by Kupiec and Revell (2001). The conditional logit modelling results from the study are listed in Table 1; the column labelled utility presents the model coefficients.

Table A1: Conditional logit results from Kupiec and Revell (2001)

Attribute	Average importance	Factor level	Utility
Flavour	40.19	Mature	1.2387
		Medium	–1.2360
		Mild	–0.0027
Appearance	28.05	Mouldy	0.5453
		Rind-off	–0.1627
		Waxed/clean	–0.3827
Use	16.38	Treat	0.1747
		Casual	–0.1400
		Cooking	–0.0347
Price	15.39	£5.50	–2.2477
		£6.50	–2.6563
		£7.50	–3.0650
Price coefficient			–0.4087
Constant			7.5377

Kupiec and Revell (2001) specify the nine alternatives shown in Table A2.

Table A2: Nine products evaluated in Kupiec and Revell (2001)

Product	Maturity	Appearance	Price (£)	Usage	Mean score	Score SD	SE
1	Mature	Traditional/mouldy	5.50	Special occasion	7.22	1.64	0.10
7	Mature	Rind-off	6.50	Casual consumption	5.75	2.10	0.13
6	Mature	Clean/waxy	7.50	Cooking	5.38	2.04	0.13
3	Medium	Traditional/mouldy	7.50	Casual consumption	5.96	1.75	0.11
5	Medium	Rind-off	6.50	Special occasion	4.94	1.65	0.10
8	Medium	Clean/waxy	5.50	Cooking	4.74	1.80	0.11
2	Mild	Traditional/mouldy	6.50	Cooking	4.10	1.83	0.12
4	Mild	Rind-off	5.50	Casual consumption	3.83	1.90	0.12
9	Mild	Clean/Waxy	7.50	Special occasion	3.00	1.80	0.11

The equation for the utility of each alternative is:

Utility, V = constant + b_1 × mature + b_2 × medium + b_3 × mild + b_4 × mouldy + b_5 × rind-off + b_6 × waxed + b_7 × (price = 5.50) +b_8 × (price = 6.50) +b_9 × (price = 7.50) + b_{10} × special occasion + b_{11} × casual + b_{12} × cooking

Note that if an attribute is not present for a particular alternative (e.g. alternative 1 is mature but not medium or mild), then the value for that attribute is zero, so it drops out of the equation. We can use the beta coefficients, labelled utilities, in Table A1 to calculate market share. Thus, for the first alternative in Table A2, total utility is:

Utility, V_1 = 7.5377 + 1.2387 + 0.5453 + 0.1747 – 2.2477 = 7.2487

The utility for each of the nine alternatives in Table A3 is then calculated as follows.

Table A3: Calculating the total utility for each alternative

Alternative	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Constant	7.5377	7.5377	7.5377	7.5377	7.5377	7.5377	7.5377	7.5377	7.5377
Mature	1.2387	1.2387	1.2387						
Medium				–1.236	–1.236	–1.236			
Mild							–0.0027	–0.0027	–0.0027
Mouldy	0.5453			0.5453			0.5453		
Rind-off		–0.1627			–0.1627			–0.1627	
Waxed			–0.3827			–0.3827			–0.3827

Treat	0.1747				0.1747				0.1747
Casual		–0.14		–0.14				–0.14	
Cooking			–0.0347			–0.0347	–0.0347		
Price 5.50	–2.2477				–2.2477			–2.2477	
Price 6.50		–2.6563			–2.6563		–2.6563		
Price 7.50			–3.065	–3.065					–3.065
Total utility	7.2487	5.8174	5.294	3.642	1.4097	5.8843	5.3893	4.9846	4.262

For each of these nine alternatives in Table 3A, the exponent of total utility is now taken. The total utility for each of the alternatives is shown in the bottom row of Table A3. Thus for alternative 1, the total utility is 7.2487 and the exponent (ie exp(7.2487))is 1406.276. The sum of the exponents for each alternative is then calculated; see Table A4. To calculate market share, we then divide the exponent of the total utility for each alternative by the sum of the total utility. Thus for alternative 1, 1406.28/2779.27 = 50.6%. Thus we would expect that if the nine products listed in Table A2 were the only ones available in a market, product 1 (mature, traditional/mouldy, used for a special occasion, price = £5.50) would achieve a market share of 50.60%.

Table A4: Calculating market share

Alternative	Total utility	Exp(Total Utility)	Market share
1	7.25	1406.28	50.60%
2	5.82	336.10	12.09%
3	5.29	199.14	7.17%
4	3.64	38.17	1.37%
5	1.41	4.09	0.15%
6	5.88	359.35	12.93%
7	5.39	219.05	7.88%
8	4.98	146.15	5.26%
9	4.26	70.95	2.55%
Sum of the exponents		**2779.27**	