CES Working Paper 02/02

DECISION SUPPORT TOOLS FOR ENVIRONMENTAL POLICY DECISIONS AND THEIR RELEVANCE TO LIFE CYCLE ASSESSMENT

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ISSN: 1464-8083

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Published by:
Centre for Environmental Strategy, University of Surrey,
Guildford (Surrey) GU2 7XH, United Kingdom
http://www.surrey.ac.uk/CES

Publication date: 2002

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(CES Working Paper 2/02)

August 2002

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ISSN 1464 - 8083

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Abstract

This Working Paper is adapted from Chapter 5 of the EngD Portfolio of Dr. Lucia Elghali (2002). It presents a critical review of developments in the understanding of appropriate decision support for complex problems with inherent uncertainty, and discusses their significance for the use of Life Cycle Assessment (LCA) to support public policy decisions. The review covers approaches based in environmental economics, risk analysis and structuring methods for strategic decision support[1].

Structuring methods for strategic decision support are shown to provide a potentially useful conceptual framework for adapting LCA to support policy decision processes. In particular, the use of LCA within a multi-criteria decision analysis (MCDA) framework through the process of decision conferencing is discussed as a potentially useful development. However, this requires a more flexible approach to LCA than is conventional, not least in adapting the Impact Assessment phase to the decision context rather than using a standard set of prescribed impact categories. Some implications of this for both technical practice and the deployment of LCA are explored.

[1] See Section 4.3.3 for a full explanation of the use of this terminology to describe a number of theoretically distinct approaches to decision support.

1 Introduction

As environmental information has generally become more freely available, governmental and industry bodies have come under increasing pressure to logically justify their policies and strategies for dealing with environmental issues, such as those associated with genetically modified food, nuclear waste and climate change. This generally requires an evaluation of multiple and sometimes competing decision criteria. This Working Paper outlines recent developments in environmental decision support for public policy, and discusses their relevance to Life Cycle Assessment (LCA) for decision-support.

Since the 1970s, methodological advances that allow the consideration of complexity in environmental decision-making processes have been developed. The use of inappropriately simplified analytical methodology for environmental decision support is often ineffective in practice, either in terms of generating robust decisions by institutions or outcomes that are accepted by society as reflecting democratic principles. The nature of this complexity embraces all aspects of this entire process, from the interaction of the analyst with decision-makers and subject matter, to the wider perception in society of the quality of decisions made by institutions. This will cover approaches based in environmental economics, risk analysis, life cycle assessment and structuring methods for strategic decision support[1] in this context. There are similarities in the nature of developments in all the decision support disciplines discussed.

Some possible ways of addressing the difficulties arising in public policy decisions because of this inherent complexity are presented. The need for LCA methodology to be adaptive to the decision context is discussed, with reference to using LCA in combination with other decision support tools. While this is a rapidly expanding field of research, the commentary is limited to a consideration of the following combinations with LCA:

- Economic approaches;
- Environmental Impact Assessment;
- Cultural theory;
- Structuring methods for strategic decision support.

[1] See Section 4.3.3 for a full explanation of the use of this terminology to describe a number of theoretically distinct approaches to decision support.

2 Environmental Decisions and Complexity

As Shakley *et al* (1996) have commented

> It is increasingly common for analysts of science and policy to distinguish between simple and complex problems, the proposition being that policy problems, and the science they demand, are now intrinsically more complex, and hence require new analytical and decision tools.
>
> (1996: 201)

Further to this statement, it is pertinent to question whether policy decisions and the scientific methods used for support were ever "inherently simple", or if this is in fact "an artefact of the restricted and reductionist approach" commonly used rather than a feature of the subject matter itself (*ibid.*: 202). Some commentators also believe that the challenges of environmental decision-making are greater due to the increased complexity of decision context and multi-disciplinary nature of the information required (Gallopin *et al*, 2001). While it is certainly valid to assert that environmental policy decisions are often difficult and complex, it is also true to say that other policy decisions where scientific methods have been employed are at least as complex, if not more so. An example here might be decisions of public health policy for the prevention of teenage pregnancy, or social policies to prevent homelessness.

Key is the observation that scientific methods are usually employed in order to conceptually simplify the reality of complex systems to allow problem solving to take place, supposedly ensuring a degree of objectivity and rationality in assessing the benefits and drawbacks of a number of alternatives. This presupposes that benefits will be optimised by the choice of a single decision alternative and that this is an efficient way of making decisions. What is in dispute is whether this is a justified approach to policy decisions and whether it has ever been justified.

Further insights are provided by Beck (1992), who compares and contrasts the role of science during industrialisation in the 19th century with current conditions, in what he argues can be described as "reflexive modernity" or the "risk society". He is highly critical of current approaches to environmental decision making and the application of traditional scientific methods of objective analysis in the identification and control of environmental risks. His particular concern is that "Science is one of the causes, the medium of definition and the source of solutions to risks" (*ibid*: 155). Thus, risks create a dependency on external knowledge to determine whether the extent of the risk is harmful, and thus foster a feeling of being incompetent in determining for oneself whether one is afflicted. Risk is seen as potentially everywhere or nowhere, but crucially can no longer be determined by one's own knowledge and experience. As Beck states, "Risk positions in this sense are springs, from which questions rise to the surface, to which the victims have no answer" (1992: 54). Thus, the reliance of the public on risk analysts and managers, and especially scientists, for information is increasing.

At the same time, the nature of the public's relationship with risk experts, science and scientists is changing. The discussion of risks has exposed the workings of science to the public, in that a hypothesis is tested by experiment and it is proved correct or otherwise by the results. However, results may be interpreted in different ways, or different experiments may conflict with or support the original research.

This is the normal state of affairs in scientific research, where the original research will illuminate areas for further study, and it may be reinterpreted in the light of other results. However, this has been kept hidden from the public almost in its entirety in the past. Current risk conflicts are dissolving the image of science as having answers to supposedly simple, logical questions such as "what level of chemical x in water is safe?" with conflicting reports appearing in the media about the same experiments.

Different viewpoints on the same results and debate, however, are normal for scientific enquiry, which in turn generates the need for more research. The difference is that this process is now more transparent, and science does not have the answers that directly address the public's risk anxieties. This situation has arguably arisen from the failure in recent years of science to address the question of interpretation of results when the outcomes are uncertain, together with a refusal to accept that different rationalities lead to different interpretations of the same data when operating in high uncertainty. This leads to differences in interpretation both between scientists themselves but also between lay people and scientists. This is the unacknowledged position in many environmental policy disputes. As Beck states,

> […] (N)ature can no longer be understood *outside of* society or society *outside of* nature. […] Environmental problems are *not* problems of our surroundings, but – in their origins and through their consequences – are thoroughly *social* problems, *problems of people*, their history, their living conditions, their relation to the world and reality, their social, cultural and political situations.
>
> (*ibid.*:80-81)

In response, it is vital that methodologies are found to adequately structure environmental policy decisions to address this level of complexity. In particular, they will need to address the socio-political and economic context of problems adequately as well as integrating scientific information, with all the uncertainties this entails. This also implies a re-examination of the possibility that in decisions involving high levels of uncertainty, scientific claims of "objectivity" may be unfounded. Thus, the aspects of fairness and accommodation of differing frames of reference for directing, conducting and interpreting research become increasingly important.

3 Features of Simple and Complex Decision Contexts

A number of commentators have attempted to draw a distinction between simple and complex decisions. They have also proposed differences in approach that may be helpful for these different contexts. Some of the main areas of development of approaches are summarised in this section.

Yolles (1999: 59) has characterised simplicity and complexity in management situations as having the characteristics described in Tables 1 and 2. This is similar to the view of Gallopin *et al* (2001: 224) that complex systems can be distinguished from both complicated and simple systems. Simple systems can be captured using a single perspective and by a standard model, which may provide either a requisite description or a solution through routine operations (e.g. mechanical motion). A system is complicated if it cannot be captured by the application of a standard model, but it may be possible to improve either the description or solution by using approximations or simulations. The complicated system may still be characterised using a single perspective (e.g. pattern of communications in a large switchboard). However, they perceive that the basic criterion separating complex systems from the other types is "the need to use two or more irreducible perspectives or descriptions in order to characterise the system." Complex systems also cannot be captured using a standard model (an example would be the movement of clouds).

There is recognition that the treatment of uncertainty in decision contexts is a key consideration. In Section 3.1, the work of Ravetz and Funtowicz (referred to in Ravetz, 1987: 102) is described which posits a distinction between "normal" and "post-normal" science. The former corresponds to a simple decision context and is characterised by low uncertainty, whilst the latter is characterised by a higher degree of uncertainty and complexity. This is analogous with the distinction made by Rosenhead between "tactical" and "strategic" organisational problems in the field of operational research (Rosenhead, 1989: 5). Observations on the requirement for different approaches to decision making in simple and complex decision contexts are explored further in this section. The extent to which a need exists to make such distinctions in environmental decision support methodology is discussed in Section 4.

Table 1 Characteristics of Simple Situations (Yolles, 1999)

Simple situations:

1 are clearly bounded and can be examined in isolation

2 are populated by a set of entities/ events

3 have information needs that are known

4 the roles and purposes of any people, groups or organisations are well known

5 are composed of differentiable problems that are either well known or probabilistically describable

6 have a form that is well known and which can change in predictable ways

7 will have known or probabilistic structural relationships across the set of identifiable parts and cause-effect relationships between events across time

8 each part:

- can be examined independently and can be optimised for the benefit of the situation
- can have a change that can be measured quantitatively
- can have deterministic or probabilistic prediction of change
- has a solution to problems in an identified form

Table 2 Characteristics of Complex Situations (Yolles, 1999)

Complex situations:

1. exist in an environment, though the boundary that distinguishes it from the situation will be unclear or uncertain

2. are populated:
   - by sets of entities/ events that may not be sensibly examinable in isolation of the context
   - by individuals, groups or organisations with roles and purposes that may not be well determined

3. have parts:
   - that may themselves be situations or problems
   - that may not be easily distinguishable from one another (a tangle)
   - that if known may not be related
   - the description and relationship of which may change with time

4. where the parts are seen as (dynamic) events across time, a simple cause-and-effect relationship between them cannot be identified

5. have a form:
   - determined by the dynamic relationship between the parts
   - that may in some way change in time
   - that may not be easily discernible

6. are world-view determined, since this defines the criteria and knowledge that can be applied to a situation under examination.

3.1 Normal and Post-normal Science

It follows that in using a scientific methodology to evaluate the magnitude and gravity of risks, it is a pre-requisite that all the scientific data required are available and that there is very little uncertainty in data quality. It is also required that all the parties interested in or involved in risk assessment are in agreement as to the framing of the assessment and the assumptions made as a result of the scientific framework within which the assessment takes place. For the majority of environmental problems, "the loss of certainty and the intrusion of ethics" destroy the basis for a "normal" scientific approach (Ravetz, 1997: 534). Ravetz has proposed the term "post-normal science" to apply to such situations, characterised by uncertainties in data quality concerning the magnitude of risks and their effects, where ethics rather than scientific principles guide outcomes.

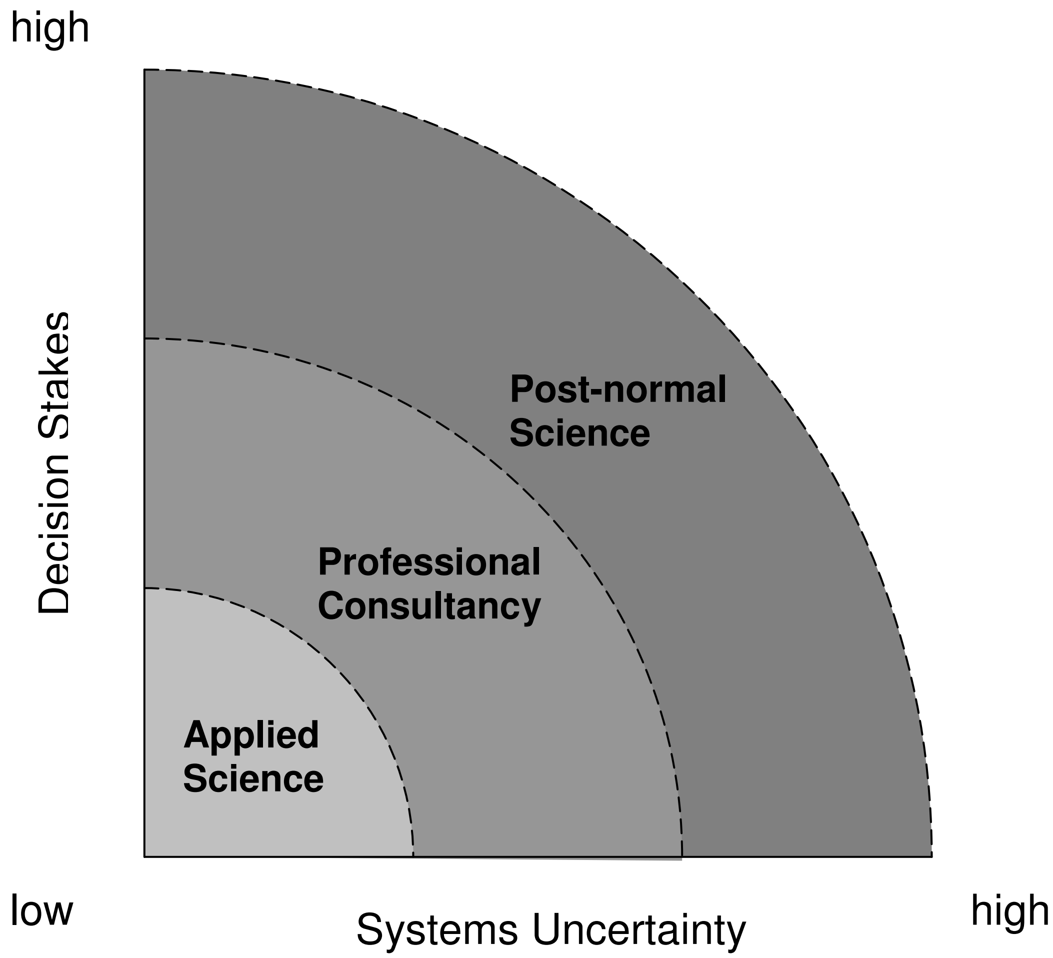
In addition, in the work of Ravetz and Funtowicz (referred to in Ravetz, 1987: 102), two dimensions of problems are identified that can help with identifying appropriate research methods for the resolution of policy decisions. These are "systems uncertainties" and "decision stakes". Systems uncertainties refer to the complexity of the system within which the decision is made, "including aspects that are technical, scientific, administrative and managerial" while the uncertainties relate to a range of possible outcomes corresponding to each set of plausible inputs and decisions (*ibid.*). The decision stakes are the costs and benefits to the parties with an interest in the outcome of the decision, including regulators and representatives of various interests corresponding to each decision. The diagram in Figure 1 illustrates their view of the interaction between these variables and the type of policy related research appropriate for the situation.

When both variables are low, "normal" scientific research (referred to as applied science) will generate knowledge about critical variables which can be used in ordinary decision processes to reach consensus on policy. When either dimension becomes moderate on the scale, a different situation referred to as professional consultancy emerges as a means of finding policy consensus. This is easy to recognise where decision stakes are low but systems uncertainty is moderate, where the particular consultant is engaged precisely because their experience, judgement or integrity in providing the requisite knowledge for the situation is valued, rather than any specifiable skill. This is the realm of the specialist consultant, such as a surgeon or consulting engineer.

When either of the dimensions is high on the scale, Ravetz (1997:534) asserts that "we are in the realm of post-normal science." Where systems uncertainty is low but decision stakes are high, he states that it is often difficult to see that this "takes the problem out of the realm of the routine" (1987: 102). However, this is a characteristic of many environmental policy problems in reality. As Ravetz points out, "if some institution sees its interests seriously threatened by an issue, then no matter how nearly conclusive the science, it will fight back with every means at its disposal, until such time as further resistance would a cause serious loss of credibility" (*ibid.*). This can be observed in some environmental and health policy disputes, such as denial by companies in involvement in poisoning people causing disabilities (e.g. asbestosis incidence in construction workers).

When one enters the realm of post-normal science, Ravetz (1997: 534) suggests that to ensure quality in science-related policy decisions requires "an extended peer community", which includes interested lay persons bringing "extended facts" to the process, namely their own lived experiences of an issue. He refers to environmental issues as an area in which this approach is likely to be of use.

Figure 1 Post-normal Science



3.2 Insights from Cultural Theory

As shown above, environmental policy decisions take place in a context that is necessarily subject to scientific uncertainty. Because of this, both lay people and experts have been found to rely upon their worldviews to assist in their response to uncertainty in the assessment of risk. They are used to extrapolate risk data in the absence of complete information. Both Schwartz and Thompson (1990) and Slovic (1994) have identified such worldviews which are culturally constructed. The four categories below correlate worldviews with anthropocentric concepts of nature and ecological management (Schwartz and Thompson, 1990). This is a simplistic insight into human values and the authors admit that empirical support for the theory is "sparse" at present. While people are actually much more complex and may adhere to more than one or all of these stances in their evaluations of risk, this does assist in understanding some of the different assumptions that are made when decisions are made in uncertainty.

- *Individualist*
  This is characteristic of enterprising and entrepreneurial people, relatively free from control by others, who strive to exert control over their environment and the people in it. A self-made businessman would be a good example of such a person. This corresponds to a view of nature as benign, in that it is predictable, robust, stable and will adjust favourably to any stresses caused in the context of human activity, providing a supportive context for this. The ecological management style associated with this would be non-interventionist and *laissez-faire*.
- *Egalitarian*
  This is characteristic of people for whom group loyalty is important but there is little respect for externally imposed rules. Decisions are arrived at by democratic means and equity is paramount. Leaders rule by sheer force of personality. Members of environmental pressure groups can be seen as exemplars of this worldview. This corresponds to a view of nature as ephemeral, where nature is fragile and susceptible to catastrophic collapse due to human carelessness. Ecological management involves the precautionary principle, to protect nature from humans.
- *Hierarchist*
  This view is one of strong boundaries between groups, with everyone knowing their place. This is characteristic of civil servants and soldiers, or any other activity with clearly defined roles and responsibilities. Nature is viewed as perverse/tolerant. Within limits, its behaviour is predictable, so regulation is required to prevent major stresses, while the system will be able to cope with minor ones. The associated ecological management style is interventionist.
- *Fatalist*
  Fatalists have minimal control over their own lives as they do not belong to any group responsible for decision making. They are resigned to their fate and do not see any point in trying to influence the outcome. Members of this group might include non-unionised employees in a workplace, or any other societal group who is not involved in decision making. The associated view of nature is of nature as capricious. The ecological management style is again *laissez-faire*, but this time because things may turn out well or be catastrophic but it is beyond the manager's control to influence the outcome.

This has consequences for the process of making policy decisions for environmental problems. Where disputes arise between parties discussing magnitude of risk, different sides will often accuse each other of stupidity and irrationality. What is often the case is that there are plural rationalities in operation; this means that the parties will be arguing from different premises and will have interpreted information according to their particular rationality. This phenomenon is seen as the action of "cultural filters" being applied by all sides in a debate to the information available, which is necessary to interpret data when information is incomplete and uncertain.

In this context, it is not surprising that, for experts to demonstrate to the general public that the magnitude of a risk posed by a policy decision is acceptable, it will not be sufficient merely to communicate technical information effectively. If the public have interpreted the available information in a different way, then their perception of risk may well be considerably different from the expert's view. In the context of siting hazardous facilities, it is the assumption that lay people are wrong in their perceptions that has led to them being labelled with the acronym "NIMBYs"

(Not In My BackYard). This is morally offensive in that it makes assumptions about the motives of those who, for example, oppose the siting of industrial activities near their homes. Some of these assumptions are explored by Sandman (1985) and are reiterated by Freudenburg and Pastor (1992).

The first assumption is that the public's behaviour is irrational and ignorant when they do not agree with a policy decision, such as a decision to site a waste facility in their locale. As described above, this tends to be because they are arguing their case from a different premise and with different biases from those who would, for example, site a waste incinerator in their locality. This perception of ignorance also is inconsistent with common experience. For example, the most spirited opposition to siting decisions has occurred in areas with inhabitants who are well educated and articulate, and who often bring with them perceptions of risk that may not have been considered by the risk assessment professionals in the decision process.

The second assumption is to label the public as "selfish", pursuing their own interests at the expense of society as a whole whilst hiding this interest behind different socially acceptable arguments. However, it is often overlooked that developers and project advocates also do this; proposers for new landfill sites or waste incinerators will purport to be hoping to ease the waste disposal problems of a particular part of the country by the benevolent gesture of siting it in a particular area. They will rarely admit publicly that it should be built to "lower the company's risk of poor balance sheet health" (Freudenburg and Pastor, 1992: 43). Both of these differing viewpoints will reflect certain benefits and disadvantages for society as a whole. It is rather disingenuous and hypocritical to label the public in this way for having different priorities from developers – this is surely to be expected from the different interest that they have in whether a project goes ahead.

This labelling of active opponents as "NIMBYs" also does not account for the heavy costs incurred by those who oppose such developments, not just financial costs but also "opportunity" costs. These include decreased leisure time, increased community tension and the risk of being labelled in a hostile manner in every sense of "NIMBY", i.e. irrational, selfish, ignorant and unpatriotic. Often, the prime motivation behind involvement is the feeling that if they do not act to defend their interests (which may be personal or socially motivated for the common good, as described in the previous paragraph), then nobody else will (*ibid.*).

If so much energy is generated by activists in opposition to policy decisions, generating new resources that could have been usefully applied in the decision process itself, the logical progression is to involve dissenting factions in the decision process itself. This issue is considered further in Section 4 below.

3.3 Arrow's Impossibility Theorem

There is a fundamental problem for a single decision-maker attempting to aggregate individuals' preferences during a social decision process, with the intention of deriving a group preference for a single course of action. Kenneth Arrow demonstrated this mathematically, by derivation of his Impossibility Theorem (Arrow, 1963). Since its publication, the work has influenced the fields of economics and political science greatly. As Stirling (1998: 103) comments, the theorum demonstrates that "it is impossible both democratically and consistently to aggregate individual preferences in plural society."

Keeney and Raiffa (1993: 523) applied his findings in the context of a single decision maker concerned about an aspect of welfare of others, attempting to aggregate a group preference for a course of action in conditions of uncertainty. The decision to be addressed is framed as "given the rankings of a set of alternatives by each individual in a decision making group, what should the group ranking for these alternatives be?" Some basic and rational assumptions concerning the aggregation of the individual's rankings are made, for which Arrow investigated the implications. The assumptions are:

> *A Complete Domain*
> There are at least two individual members of the group, at least three alternatives and a group ordering is specified for all possible individual members' orderings.
>
> *B Positive Association of Social and Individual Orderings*
> If the group ordering indicates that alternative A is preferred to alternative B for a certain set of individual rankings, and if:
> (1) the individuals' paired comparison between alternatives other than A are not changed;
> (2) each individual's paired comparison between A and any other alternative either remains unchanged or is modified in A's favour;
> then the group ordering must still imply A is still preferred to B.
>
> *C Independence of Irrelevant Alternatives*
> If an alternative is eliminated from consideration and the preference relations for the remaining alternatives remain invariant for all the group members, then the new group ordering for the remaining alternatives should be identical to the original group ordering for these same alternatives.
>
> *D Individual's Sovereignty*
> For each pair of alternatives A and B, there is some set of individual orderings such that the group prefers A to B.
>
> *E Nondictatorship*
> There is no individual with the property that whenever he prefers alternative A to B, the group will prefer A to B regardless of the other individual's preferences.
>
> (adapted from *ibid.*: 523-524)

Arrow found that assumptions A to E were inconsistent, as he proved that there is no rule by which the individuals' rankings can be combined into a group preference and still comply with these five assumptions. The implications of this are that even if the quality and quantity of data available and degree of consultation involved in an analytical method used for decision making are high, this method cannot "fulfil the role of a democratic political process" (Stirling, 1998: 103).

An alternative way of expressing this would be to state that the use of a purely analytical (or scientific) tool is unable to address the conflicts of interests or divergent frames of reference between different actors, which are central to environmental decision making in complex contexts. It follows that "(t)he notion of a single discrete 'objective' social preference ordering is theoretically weak and unlikely to be achieved in practice in a pluralistic society" (DETR, 2000:108). Arrow's work is important because it implies that another means is required to accommodate differences in values within decision making activities: this is a priority if the process is to be perceived as fair and democratic.

4 Commonly Applied Tools for Policy Decision Support

This section explores how the insights derived from a consideration of complexity, cultural theory and Arrow's impossibility theorem have been addressed in some current decision support methodologies for environmental public policy. The specific disciplines discussed are environmental economics (with cost-benefit analysis as an example typical of such approaches), risk assessment, life cycle assessment and operational research.

4.1 Environmental Economics

Cost-benefit analysis is a form of economic project appraisal. In the sphere of environmental policy decisions, it has been used for individual projects (such as evaluating the costs and benefits of stricter emissions limits at one facility) or a programme of activity viewed as a series of projects (such as renewing sea defences to protect the UK from coastal erosion). According to Pearce *et al* (1992: 121), this involves a comparison of costs and benefits. If the benefits exceed the costs, the project is viable in principle. Otherwise, the project should not go ahead. The basic formula used to calculate the Net Present Value (NPV) is given below.

$$\sum_{t=0}^{t=T}\{B_t - C_t - E_t\}\,(1 + r)^{-t} > 0$$

where B_t is the benefit arising t years from the present, C_t is the cost at time t, E_t is the environmental damage done by the project (if the project results in improvement, the term is positive) and r is the annual discount rate.

This appears to be a straightforward process of adding up all the costs and benefits of a project and then making a decision to go ahead if the benefits outweigh the costs. However, the history of public policy applications of cost-benefit analysis in the UK suggest that there are problems with using monetary values to describe benefits and disadvantages associated with projects. It is simply not acceptable to all sides in a policy debate to reduce preferences to monetary costs and benefits. This violates the principle of Arrow's impossibility theorem and denies the existence of complexity in the decision context. An explanation of the main objections to the use of this methodology follows.

4.1.1 The Environment as an "Externality"

In economic terms, the costs of environmental damage and benefits of good environmental quality are examples of external costs and benefits or externalities. They are outside the normal accounting framework, which presents problems in generating any private interest in protecting the environment. Externalities are third party (or spill-over) effects from the production and/or consumption of goods and services for which no appropriate compensation is paid. Externalities can cause market failure if the price mechanism does not take into account the social costs and benefits of production and consumption. Clearly, for economists at least, the problem with many environmental services is that they are treated as free goods. Pearce *et al* (1992: 5) assert that they have a zero price simply because no market place exists in which their true values can be revealed through the acts of buying and selling. This leads to overuse of environmental resources. The argument for finding real economic prices for environmental goods is that this will reduce their use. This is illustrated in Figure 2.

Figure 2 Environmental Problems Due to Absence of Markets (Pearce et al, 1992: 6)

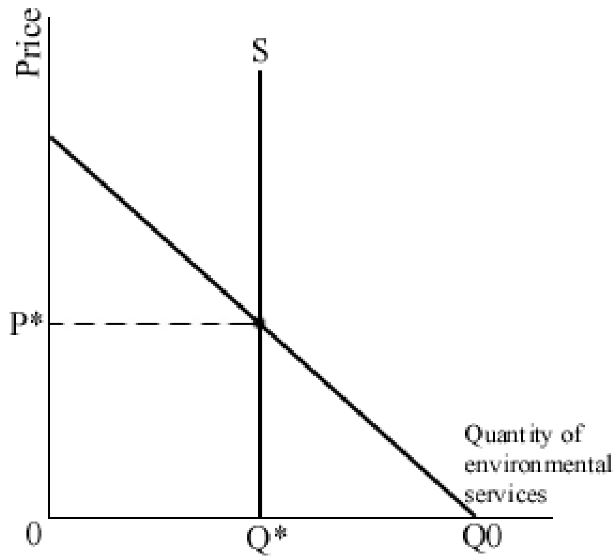


Figure 2 illustrates the demand D for environmental goods. If the good was priced, the demand would increase as the price drops. However, the supply is fixed, shown by the vertical supply curve S. If the good was priced, its price would settle at P* (the equilibrium price) and would use Q* amount of the good. Where no market exists, the price is zero and the amount of the good consumed is Qo, which is in excess of what is desirable. Therefore, if a market did exist, this would prevent the excessive use of environmental goods. However, even a price at P* may not necessarily prevent overuse of environmental goods over time.

In order to create markets or influence existing markets for environmental goods, it is seen as necessary to value them in monetary terms. This has been achieved for a number of pollutants, but the approach also has a number of drawbacks. However, if the arguments against pricing are put to one side for the moment, it is asserted that there are valid methods of converting preferences placed on environmental goods into monetary values, the chief of which is *contingent valuation* (see below). The difficulties inherent in contingent valuation are reviewed in Section 4.1.3.

4.1.2 Pricing Methodology

Pearce et al (1992: 60) have described a method of describing the total economic value of environmental goods. This has three components, which added together give the total value of the environmental asset. *Actual use values* derive from the use of the environmental resource in question. For example, if the valuation is for mud flats, ornithologists would be said to use it for the facility of bird watching. These economic values are the simplest to derive, for example from the revenues from tourism. *Option values* are more complex and describe the value of the environment as a potential benefit rather than an actual present use value. This is essentially a willingness to pay for the preservation of the environment against some probability that it will be used in the future. *Existence values* are the most difficult component to measure, and attempts to describe the intrinsic nature of an environmental good. It is unrelated to personal benefit and is not concerned with a direct use of an environmental good. An example would be the value that someone places on a species such as the humpbacked whale that they may never see.

There are a number of different methods of eliciting these values to price environmental goods (*ibid*: 63). Direct valuation techniques consider the environmental benefit of a good and attempt to directly measure its value. Examples suitable for these methods would be better air or water quality. The economic value of the gains may be found by looking for a surrogate market or by using experimental techniques. Hedonic pricing is an example of this approach, where property values are used to analyse the extent to which property values vary with differences in environmental quality, and from this to infer how much people are willing to pay for improvements in environmental quality.

Contingent valuation also uses a direct approach, which is to ask people what they are *willing to pay* for an environmental benefit and/or what they are *willing to accept* as compensation to tolerate an environmental loss. The aim of the procedure is to elicit bids from the individual people in the study as if a market for the good existed. The method of payment would be known as would the environmental good in question, such as a local entry charge to a park or green space. The questioner then suggests the first bid and the respondent will agree or disagree with the price. The price is then increased for *willingness to pay* studies until they will not pay the extra increment. This is the maximum willingness to pay. The process works in reverse for *willingness to accept* methods. The major attraction of these methods is that they are in theory applicable to most projects and policies and will often be the only available technique for establishing any form of price.

4.1.3 Denial of Complexity

4.1.3.1 Divergent Values

There are a number of ethical problems raised by the process of attaching monetary values to environmental resources. The first of these is that the economic approach to valuation is an entirely anthropocentric one. The discussion centres around the environment's uses, reminiscent of a utilitarian approach. This results not in a universally applicable and rational measuring rod for describing the worth of environmental goods, but in disputes about the narrow description of the environment that this entails. Principal disputes tend to revolve around spiritual and moral concerns which people claim are incapable of valuation. This in turn tends to provoke a response from economists that this stance is irrational. As Adams (1989) neatly summarised in his report on the use of cost-benefit analysis by the Department of Transport,

> The opposition (*to economic valuation of London's green spaces*) inhabits a less tidy world full of incommensurables. In this world there are no simple linear measures of progress. Conflicts are resolved by disputation and persuasion, not computation. It is recognised that where one side values highly what the other side considers worthless, no method of calculation will be capable of settling the issue. Economistic methods which pretend to such a capability will inflame debate by their irrelevance, not settle it.
>
> (1989: 13)

However, Adams (1993: 251) reserves his most withering contempt for contingent valuation methods. He points out that a *willingness to pay* value is constrained by a person's budget, whereas the *willingness to accept* compensation value may be infinite. For example, no amount of money is likely to compensate someone stricken with a fatal disease. It follows that the sum a person is able to pay to prevent a loss is rarely an accurate measure of the loss experienced by that person.

It is worth exploring his example of a passenger travelling in a smoking carriage on a train, to elicit some of the ways in which the framing of the questions asked can influence people to give different economic evaluations of environmental goods (p252). The definition of costs and benefits is crucial to the choice of measure adopted. The legal or moral context of an environmental problem can change the perception of it as a cost or benefit. Consider Table 3, which illustrates a bargain struck between two travellers, one a smoker and the other a non-smoker, sharing a compartment on a train. The outcomes change depending on whether the railway company's policy on smoking is permissive or restrictive.

Table 3 Illustration of Bargaining Positions According to Different Smoking Policies on a Train (adapted from Adams, 1993: 252)

	Smoker	**Non-Smoker**
Permissive Smoking Rule	Willingness to accept compensation for foregoing the right to smoke	Willingness to pay for the benefits of a smoke-free journey
Restrictive Smoking Rule	Willingness to pay for the right to smoke	Willingness to accept compensation for foregoing the right to fresh air

Under the permissive rule allowing smoking, fresh air is viewed by the non-smoker as a benefit. The amount paid depends on how intolerant he is of smoke and what he can afford. The amount the smoker will accept as compensation will depend on the strength of addiction, income or compassion (which will indicate payment in moral satisfaction). Conversely, under the restrictive rule, the smoker's *willingness to pay* will be influenced by the strength of addiction and income while the non-smoker's *willingness to accept* compensation will depend on aversion to smoky air and how badly he needs the money. It is difficult to imagine a civilised smoker requiring a huge amount of compensation to forego the right to smoke, but it is easy to imagine an asthmatic refusing a large sum of money to continue to be able to breathe easily.

It is easy to extend this analogy to environmental goods. If smokers represent polluting industry and non-smokers opponents of pollution, then to ask the latter what they would be willing to pay is to assume a permissive rule. Adams views this as "tantamount to basing a cost-benefit analysis on a presumption in favour of development. It is to assert that people have no right to clean air and water, to peace and quiet, to their architectural heritage, to cherished landscapes, or to habitats for endangered species. These are all transformed into privileges for which people are expected to pay out of limited budgets" (1993: 253). This raises some serious questions about vertical equity. If the poorer members of society cannot afford to pay so much for environmental goods, does this mean that they are less entitled to enjoy them? This seems to be the unavoidable conclusion. The way that the valuation process is framed is crucial in that it limits responses of participants, with political consequences.

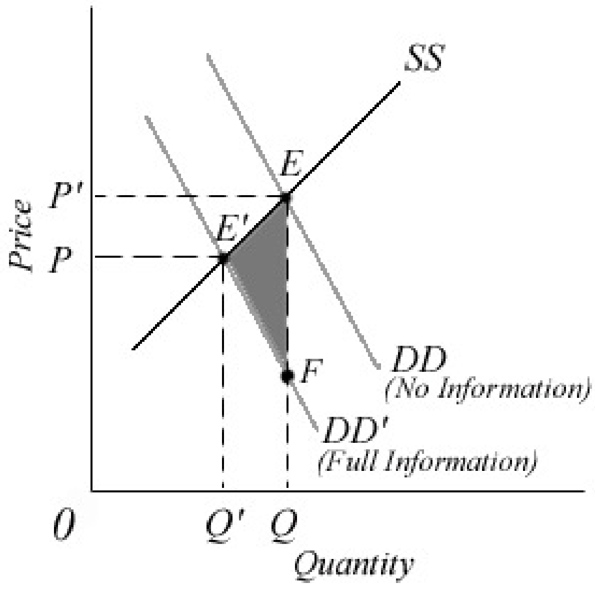
It is difficult (and perhaps impossible to attempt, with reference to Arrow's work) to put a monetary value on negative externalities such as those arising from the extraction of aggregates. The attempt to do so by the Department of the Environment, Transport and the Regions (DETR) in order to impose an aggregates tax in 2002 has been unacceptable to both extremes of the policy debate, echoing Adams' concerns. An economic evaluation of the costs and benefits of quarrying was commissioned, which suggested that a rate of £2 per tonne of aggregate produced should be imposed as a tax. Environmental groups criticised the lack of breadth of environmental appraisal from which the eventual price of the tax was to be imposed, claiming that the tax would be set at too low a level. Using contingent valuation methods, the Government re-evaluated the likely environmental externalities of aggregate extraction and transport. From the figures, it seemed likely that a rate of around £5 per tonne would be imposed at some point in the future (ENDS, 1998). Producer companies disputed the charge, but the researchers acknowledged that the figure was an underestimate due to the exclusion of a number of important environmental effects from the study. The researchers acknowledged that they had not accounted, for example, for existence values for the quarrying of Areas of Outstanding National Beauty and National Parks. They also did not evaluate the effects of marine dredging on the inshore fisheries ecosystem, or its damage to the fishing industry generally (DETR, 1998). However, despite the fact that this contingent valuation study demonstrably underestimated the costs associated with environmental damage for aggregate extraction because it was incomplete, the tax has been set even lower at £1.60 per Tonne when it entered into force in April 2002 (HM Customs and Excise, 2002). This suggests that there are undisclosed political motives involved in the setting of an "appropriate" rate for the tax other than environmental protection. This is contrary to the principle of "transparency" in public policy decisions, and deserves to be challenged by all sides in the policy debate on the grounds that the charge imposed is inconsistent with the stated policy objectives of the decision-makers.

The imposition of this tax contributes nothing to the real debate, which concerns the politics and ethics of destroying landscape to provide aggregate when a higher degree of recycling of existing materials for construction could prevent this. Indeed, it is a concern of numerous environmentalists that when regulatory agreements such as taxation are negotiated between the regulator and industry, that the finance department's role will be enhanced and augmented as a member of the environmental policy community. This enhanced role has a number of consequences, according to Macdonald (1995). Firstly, it adds a state actor to the policy decision-making process whose first commitment is not environmental protection. It is difficult to avoid a conclusion that the tax will be judged more on its revenue-generating potential than its environmental effectiveness. Secondly, finance departments who have a traditional view of the role of taxation, may be ideologically opposed to the use of taxation for regulatory purposes and may seek revenue primarily from other sources. Support for the process of internalising costs both amongst state and non-state actors may also be less when the chosen instrument is tax rather than law. Law is an instrument which carries with it moral sentiment. However tax carries no moral sentiment, simply stating that one activity will cost more than another. It is precisely because of this lack of moral authority that a price imposed by a tax will be less acceptable than a similar price imposed using legislation.

4.1.3.2 Uncertainty

Uncertainty about the effects of pollutants is curiously absent from the debate about valuation. A problem with monetary valuations is lack of knowledge about the effects of using environmental resources, including the effects of emissions, which represents an unknown future risk. Risk and lack of information are characterised as sources of market failure. Figure 3 illustrates supply and demand for an unsafe good. Consumers are unable to discover the safety risks associated with a particular good. Free market equilibrium occurs at E. When a government agency subsequently provides information about the good, the demand curve shifts down to a new equilibrium at E'. This is where the full information valuation of an extra unit of the good equals its marginal social cost. The provision of this information prevents a welfare cost of E'EF, which arises when uninformed consumers use the wrong marginal valuation of the benefits of that good.

Figure 3 Information and Unsafe Goods (Begg, 1987: 331)



Decision-making for environmental protection policy is a complex activity that is necessarily carried out within areas of scientific uncertainty. This uncertainty may be better described as ignorance where there is "incomplete knowledge, contradictory information, conceptual imprecision, divergent frames of reference and intrinsic complexity or indeterminacy of many natural and social processes" (Stirling, 1997: 525). The widespread use of the "precautionary principle" implies that this is the acknowledged condition in many areas of environmental policy (*ibid.*). Because of this, both lay people and experts have been found to rely upon their worldviews to assist in their response to uncertainty in the assessment of risk. They are used to extrapolate risk data, in the absence of complete information.

We may not know for decades if assumptions made about the long-term behaviour of a contaminant were in fact correct. This will of course apply as much to any analytical method of calculating the correct level of environmental protection, including the classic "command and control" style of legally based regulation. However, the calculation of monetary values for environmental damage from incomplete information about effects is worse because the uncertainty is masked, especially in cost-benefit analysis. For example, a cost-benefit analysis to decide whether to use chlorofluorocarbons or propane as a coolant in fridges would give different evaluations of costs and benefits depending on whether it was carried out today or in the 1950s. The danger inherent in this neat way of summarising "preferences" is that it silences any debate about the consequences. In areas of uncertainty this political debate between actors is essential to interpret incomplete factual information in the interests of procedural fairness and democracy.

This brief consideration of the difficulties involved in making economic valuations in the present that reflect future risks leads to a consideration of setting discount rates in NPV calculations. A particular concern amongst environmentalists is that the way that discount rates are set means that the environmental risks of today are simply transferred to future generations. As Pearce notes, "[M]uch of the modern discussion on how to integrate environmental factors into investment appraisal has tried to do so by making adjustments to discount rates" (1992: 145). However, this is to miss the point of the environmental argument. The uncertainty regarding future environmental effects of current activities consequentially leads to an artificially low market price. It is not clear that it would be possible to predict such effects fully under any circumstances and hence it is likely that no discount rate applied will ever reflect the reality of the situation. The heart of the matter is how environmental risk should be managed and whether this is reducible to a monetised cost or benefit if the risks, for better or worse, are unknown.

Howarth notes that "the standard techniques of cost-benefit analysis imply that essentially no weight is attached to policy impacts that occur more than a generation in the future" (1996: 263-264). Where ethical concerns underpin many of the debates relating to the environment, then the question is raised of whether it is proper to approximate all values to strict monetary valuations. Howarth suggests that the answer may be yes if the aim of policy is to improve "economic efficiency", but that the answer may be no if the objective relates to income distribution or the protection of fundamental rights, since "economic theory lacks definitive criteria for identifying optimal policies" (1996: 264).

Discounting is used in cost-benefit analysis to convert costs and benefits that are gained at any point in time into present value units. It is essentially concerned with the trade off of experiencing future and present benefits. In general terms, market prices are assumed to reflect preferences, so that market rates of interest should be used. In practice, a range of interest rates may be used, since the rates for investments increase depending on the magnitude of risk associated with the investment (1996: 265). Generally, Howarth does not disagree with the use of cost-benefit analysis except in the case of "hard uncertainty", where "fundamental ignorance" regarding the likely effects of environmental system changes in the long-term implies that they are likely to generate "surprises" (1996: 268). In these cases it is difficult to defend the use of cost-benefit analysis because of difficulties in reliably quantifying the costs and benefits. The market cannot reflect a true rate of interest that includes future environmental risks associated with the investment because of ignorance regarding the true risk.

A good example of this type of difficulty is the bankruptcy of many of the Lloyds Names, due mainly to the heavy investment of Lloyd's insurance syndicates in asbestos producers for short-term profits. When the link with asbestosis was proven, the Names received thousands of compensation claims from sufferers in the 1980s and 1990s. The initial investments in the technology were made in the 1920s. A pertinent question is whether a blanket change in the discount rate used to appraise investments in the 1920s could reflect the scale of disaster inflicted on sufferers of asbestosis in the future, without prejudicing the viability of numerous other technological projects with unknown risks at the same time. A blanket change in the discount rate used would be a manifestation of "the precautionary principle". This is often advocated in environmental risk debates as a sound approach, and shifts the burden of proof to industry to prove that a substance will not cause harm. This is enshrined in EU legislation, and many global agreements. However, this does not resolve the initial lack of scientific information on which to base judgement and is at best a trade-off of possible physical risk to people or the environment against the economic and social benefits derived from the risk. The answer to the question posed must surely include the view that the unknown environmental risks must be dealt with separately from the question of economic viability.

While it is agreed that it is inappropriate to attempt valuation in such uncertain circumstances, I would go further than this to suggest that the problems outlined in 4.1.3.1 concerning valuation also invalidate the basis for valuation of environmental problems where the consequences are known. As Norgaard notes, "[M]arkets themselves do not provide for intergenerational equity any more than they provide for intragenerational equity. 'Trickle ahead' is no more suitable as an operating norm for development than is 'trickle down'" (1993).

4.1.4 Summary

While the use of cost-benefit analysis seems potentially advantageous, it has some serious drawbacks. Not least amongst these is the process of attempting to value environmental goods and services, which have been shown to mask difficulties in the social appraisal of projects and policies. As Stirling (1997) put it

> Without systematically addressing issues such as ignorance and plurality in value judgements, environmental appraisal becomes more vulnerable to use as an expedient cover for decisions that are made on the basis of entirely different considerations. It is well recognised that environmental decision-making should be founded on the best available scientific data and most rigorous theoretical models. It is less well recognised that rigorous policy analysis in a plural society also means systematic and transparent attention to the exploration and accommodation of divergent value judgements.
>
> (1997: 535)

Ravetz (1994) agrees with this analysis and has criticised the application of economics in this area as an "elite folk science", warning that "(a)ny science that assumes certainty and relegates even the most urgent problems to 'externalities' will seem increasingly irrelevant and bizarre." Ultimately, the only truly satisfactory way of addressing issues such as environmental protection, where divergent values and interests are characteristic, is through political, democratic processes which have an appreciation of the complexity of environmental problems. To use a cost-benefit analysis method as a basis for policy decisions alone is to disregard Arrow's impossibility theorem, that group preferences cannot be aggregated into a single preference by the use of an analytical method. If the aspiration of economic environmental valuation is to provide a simple, objective way of solving an essentially political problem, then it is of itself part of the problem rather than a solution.

4.2 Risk Analysis

In order to understand the changing nature of risk analysis, a definition is required of what this means. It has been deemed necessary by the US and now also the UK to separate the functions of risk assessment and risk management for the setting of environmental standards (Royal Commission on Environmental Pollution, 1998). Thus, risk assessment is seen as a scientific evaluation, which determines the characteristics of a hazard and likelihood of the hazard causing adverse consequences (risk evaluation). Feeding into this are the results of experiments to observe the effects of an agent on the population and field trials to estimate exposure of populations to the agent, extrapolating data where necessary (risk estimation). Risk management is a policy process in which the options for regulating the agent and measures are instigated to control the likelihood of harm occurring. By contrast with risk assessment, this is not just a scientific process, but includes economic, social and political variables in order to make a good regulatory decision. Risk management also includes the process of risk communication, the process of interaction between risk experts and the general public to ensure that the technical risk is communicated effectively.

However, the "scientific" risk assessment phase also often has a non-scientific evaluation built in to it, purely because it is carried out by people making value judgements about whether a risk is significant, which is not acknowledged. For this reason, it is also necessary to examine the changing relationship between the public and risk experts, and the nature of environmental risks.

4.2.1 Problems in Communication between Risk Experts and the Lay Public: What is Risk?

Traditionally, communication on risks has involved advice from experts on the format and content of risk information, together with the objective of assisting the public to comprehend the technical information presented. The objective of the communication of such information is also of importance. Slovic and MacGregor (1994: 2) identified four types of risk communication objectives as follows:

- To provide information and to educate people about risks and risk assessment generally;
- To effect behavioural changes and protective action to reduce risk;
- To provide direction and guidance during disasters and emergencies;
- To effect joint problem solving in risk management decisions and resolve health, safety and environmental controversies by involving the public.

All such endeavours to communicate risk information effectively presuppose that the degree of risk will be worked out in the first instance by an expert using risk assessment methodology. All that then remains is to get the message across about the degree of risk to the public. This sounds like a simple case of getting the public relations right. Young (1990) certainly agrees.

> […] the risks associated with industrial neighbours are often misunderstood, if they are understood at all. […] Although the designers and operators of industrial facilities generally have the technical expertise to identify the hazards and quantify the risks posed by their operations, they often find it difficult to communicate this knowledge to the general public in a constructive and credible manner.
>
> (1990: 22)

4.2.2 Risk Assessment

Studies of risk assessment have their origins in the attempts of physical scientists to quantify risks. In this context, Adams (1995) states that risk may be defined as "the probability that a particular adverse event occurs during a stated period of time, or results from a particular challenge. As a probability in the sense of statistical theory, risk obeys all the formal laws of combining probabilities" (1995: 8).

This was the definition given by the Royal Society in 1983 in their report entitled Risk Assessment. There was agreement in the document that what was required was objective measurement of risk, as though through measurement and collection of data it would be possible to arrive at a value for "actual risk" (*ibid.*). Such traditional approaches to risk assessment have focussed on distinctions between "objective" or "real" risks, and "subjective" or "perceived" risks. In the former category are risk estimates made by experts using probabilistic science, the latter being the lay person's rather different perceptions. This position is neatly challenged by Thompson (1990), who feels that this has legal and moral implications:

> …distinctions between reality and perception have implications for law and policy because the probabilistic concept of risk provides a new basis for identifying and assessing risks. Traditionally, the principal criterion for the riskiness of an action has been the judgement of an archetypal "reasonable person", but it is precisely the judgement of the typical person that Starr[2] wants to set aside as mere perception.

"Objective" risk estimates are made by compiling data on the probability of a hazard actually causing harm. For example, there are estimates made for the risk of harm from many "hazardous" activities, such as smoking, working as a miner, crossing roads, etc. Whilst qualifications are often given for the figures, the belief remains that provided the means of measurement is right, there will be a way of measuring one absolute value for the probability of a risk being realised. This is defined by Adams as a "Kelvinist" view of risk, after Lord Kelvin who once said "Anything that exists, exists in some quantity and can therefore be measured" (1995: 10). This is a position typical of positivist physical scientists involved in risk assessment, who unsurprisingly display a desire to study risk from an objective, detached and reductionist perspective, as commensurate with their training.

This is based on the assumption that scientific evaluation of risks can determine how to rank risks, and which ones are worthy of consideration and control, an approach

[2] The paper quotes Chauncey Starr at a 1979 conference of risk analysts, espousing a view similar to that in the preceding paragraph to this quotation.

usually known as "technocratic" risk management. Here, scientific principles guide risk policy decisions, which are then subject to peer review. This type of risk management can work well if the scientific elite are trusted to make such decisions in the public interest and the issues are clear cut. However, many have criticised this approach as many aspects of risk debates are carried out in areas of scientific ignorance and uncertainty; it is argued that science is then only an informant to the debate, not the deciding factor on what action should be taken. For example, in his narrative of the BSE scandal which rocked the UK in the 1990's, John Durant (1998) questions how the Conservative government could have relied so heavily on its scientific advisers to the detriment of involving other interested parties, when it was clear that not much was known about BSE or its relationship with Creutzfeldt-Jakob disease. The result was a decline in trust of risk policy makers, since the risk of human infection was seen to be underestimated.

By 1992, the Royal Society updated its advice. In its later report on risk, the first four chapters appear to broadly agree with the earlier document, reiterating the difference between "real" and "perceived" risk. Chapter 5 goes on to contradict this assertion:

> the view that a separation can be maintained between "objective" risk and "subjective" or perceived risk has come under increasing attack, to the extent that it is no longer a mainstream position
>
> (Adams, 1995: 9).

The contention of this section of the report is that risk is "socially constructed" (*ibid.*) and is completely at odds with the "Kelvinist" approach described above. This dichotomy of views epitomises the disagreements between the physical scientists and social scientists invited to participate in the writing of the report. The latter had been invited for the first time to participate. This dichotomy has serious implications for the way in which risks are communicated to groups outside of the risk experts' "Kelvinist" paradigm.

4.2.3 Differences in the Perceptions of Risk

Why do experts and lay people perceive risks differently? Commentary on the nature of risk has evolved from earlier work accounting for differences in perceptions of risk between people in different circumstances. Concepts of risk perception are pivotal in management practices, since this affects the way in which messages about risk are communicated. As Otway and Wynne (1989) assert:

> …it is apparent that simplistic models of risk perception have obscured our view of the social interactions and contexts which define authentic risk communication. Thus, the risk communication paradigm rests on unarticulated assumptions about who is communicating what, to whom, and in what context.
>
> (1989: 141)

Slovic *et al* (1985) and Renn (1990) suggest that there are a number of factors governing perception of risk. One framework for characterising perceived risk is the psychometric paradigm, where the process of cognition of risks has been investigated. It has been found that people will make quantitative judgements about the current and desired level of risk that is posed by a hazard, and its desired level of regulation. This judgement is related to properties of that hazard such as:

- Its status with respect to characteristics such as voluntariness, dread, familiarity, controllability;
- The benefits that the hazard provides to society;
- The equitable distribution of risks and benefits;
- The number of deaths caused by the hazard in an average year;
- The number of deaths caused by the hazard in a disastrous year.

(Slovic and MacGregor, 1994: 5)

An alternative explanation of risk perception is given by the model of risk compensation postulated by Adams (1995). He points out that this "risk thermostat" model is a conceptual rather than operational one. He states that:

- Everyone is predisposed to taking risks, and the extent and magnitude of the risks taken varies from person to person and is influenced by the potential rewards associated with the risks;
- The perceptions of risk are influenced by experiences of accident losses. These losses may be personal or have been experienced by others;
- Individual decisions to take risks indicate a balancing of the perception of risk against the propensity to take risks;
- Accident losses are a consequence of taking risks. The more risks one takes, the greater the rewards and losses incurred, on average.

Cultural factors are also important in shaping views about the nature of risks. Slovic and MacGregor (1994: 6) found that dread was most closely related to the public's perception of magnitude of risk, whilst experts do not evaluate risk in these terms. Experiences of risk also have a tendency to be amplified by social processes, where factors affecting perception include blame attributed to regulatory bodies or industry and the quantity of media coverage of a particular risk (Renn *et al*, 1992). In contrast, experts tend to correlate risk with expected annual mortality. This indicates that the concept of risk is defined differently by experts and lay people. While lay people often do not have all the technical information available, their concept of risk is more complex and encompasses concerns which are not taken into account by expert assessments of risk. The importance of this insight is that unless risk management and communication decisions take place as part of a process to incorporate both methods of risk perception, they are destined to be unsuccessful (*ibid.*).

4.2.4 Summary: Embracing the Complexity of Risk

Risk assessment and management practices have been developing from a technocratic approach towards current best practice which involves a much greater emphasis on the social construction of risks. Fischhoff (1995) has charted developments in risk communication over the past twenty years and has identified the following developmental stages:

1. All we have to do is get the numbers right.
2. All we have to do is tell them the numbers.
3. All we have to do is explain what we mean by the numbers.
4. All we have to do is show them that they have accepted similar risks in the past.
5. All we have to do is show them that it's a good deal for them.
6. All we have to do is treat them nice.
7. All we have to do is make them partners.
8. All of the above.

(1995: 138)

This evolution of process illustrates the transition from "scientific" or objective approaches to risk, to those where the social context is also given consideration. The rapid development of this field, particularly in the last decade, has evidently been driven by two factors:

- The changes in understanding of risk to include social factors as a legitimate field of study;
- The lack of success of traditional technocratic risk management methodologies in securing public confidence. This is illustrated by the increasing lack of success in finding acceptable sites for "hazardous" facilities, such as waste incinerators, despite adhering to traditionally accepted practices in risk communication.

This has increased the interest in developing participatory means of identifying and assessing risks[3]. This involves either public participation in risk decisions, or stakeholder participation in decisions. Public participation involves the public directly in organised groups such as citizen juries or panels, where the policy outcomes generated may be either advisory or mandatory. Stakeholder participation is similar, but involves those who have a direct stake in the outcome of a risk management decision e.g. industry groups, environmental campaigners, citizen pressure groups, etc. The great advantage in using the groups is that it builds trust in the policy process and is educative. It also does not rely on trust of the policy makers or scientists involved as a prerequisite, in contrast to the technocratic style above. It is also difficult to litigate, since responsibility for decisions is shared. However, it is expensive, difficult to reach consensus and easy to manipulate, since there is little quality control. It has proved especially useful in making controversial policy decisions, such as the siting of hazardous facilities.

An example of such a process using fairness as the guiding principal of risk management was successful in a Swiss case study carried out by Renn *et al* (1996).

[3] Evidence of the increased interest in participation amongst environmental professionals in the UK is demonstrated by the publication of "Guidelines on Participation in Environmental Decision-Making" by the Institute of Environmental Management and Assessment (IEMA) in 2002. This forms part of its "Perspectives" series of publications, prepared by IEMA in collaboration with a working party drawn from representatives of local government, industry, academia and specialist consultants, which was chaired by Judith Petts, Professor of Environmental Risk Management at the University of Birmingham.

The objective was to site a solid waste landfill. Phase 1 of the study identified thirteen eligible sites using scientific criteria such as hydrogeological features, and did not include the public. Phase 2 had the main task of reducing the choice to three to five sites using a participatory decision process. This was achieved successfully. Several aspects of the process are pivotal to its success:

- Giving everyone in the affected population a chance to participate;
- Building an atmosphere that encourages people to discuss anything that comes to their minds and to criticise or challenge anything that anyone else says;
- Agreeing on a means to resolve disagreements before they arise;
- Giving people the right to ask for new discussion leaders or experts and to influence the agenda;
- Giving people time between the meetings to discuss the result of each meeting with their constituents, but reserving at least a day or two days for finalising the recommendations;
- Organising a group delphi to clarify expert certainty and uncertainty;
- Providing expert witnesses to educate the participants;
- Providing pre-reviewed informational material;
- Visiting the potential sites.

(*ibid.*: 165)

Risk assessment and management can be characterised as a field in which complexity is beginning to be addressed in earnest. The insights from this field of study, particularly in capturing social considerations in decision processes, are applicable to other environmental policy disciplines. It is to be hoped that this diffusion will continue in future.

4.3 Structuring Methods for Strategic Decision Support

Rosenhead (1989) has described in detail a “crisis which has afflicted more conventional methods of rational analysis" during the 1970s and 1980s (1989: 1). In order to explain the nature of this crisis, he has made reference to the developments in operational research (OR) methodology during this time in detail. He used OR in his publication as a context within which to discuss the crisis, since he considered that "most of the methods featured […] have emerged out of operational research, or are considered by their practitioners to be a part of OR" (1989: 3). However, he also acknowledged that very similar arguments have arisen in other related fields. As a result, a number of different methods are listed in his work as contributing to a new and emerging approach to strategic decision support.

Essentially, a split emerged in the OR community between supporters of what Rosenhead refers to as “rational comprehensive planning” (*ibid*.: 3) and those who felt that reform was required because of its limiting and technical nature. Rational comprehensive planning consists of five stages:

1. Identify objectives with weights;
2. Identify alternative courses of action;
3. Predict the consequences of actions in terms of objectives;
4. Evaluate the consequences on a common scale of value;
5. Select the alternative whose net benefit is highest.

(*ibid*.: 3)

In OR, stage 1 represents the identification of the objective function of the exercise, stage 3 is where modelling of cause and effect relationships takes place and stage 5 is the identification of the optimal solution (usually using a computer program). As in the field of risk assessment and management, although arguments were made plausibly against this type of analysis from a theoretical perspective, eventually it was the unfeasibility of its use on large and complex projects that eventually undermined its credibility. This corresponds with the observation that in US business enterprises, operational research had been demoted from application at corporate level (strategic problems) to secondary business problems (tactical problems) *(ibid*.: 5). In this view of operational research, it is an example of “hard systems thinking”, where only one problem is recognised that requires a solution and is well structured. As Rosenhead observes, “(t)he task of the analyst is to recognise it, and then turn the handle on the analytic sausage-machine”. The method is in principle “practitioner-free”.

In order to make the transition from the use of operational research methodologies for tactical situations alone to problem solving in strategic contexts, Rosenhead argues for a broader, problem structuring approach which gives more consideration to the decision context. In particular, he calls for a better accommodation of complexity, uncertainty, conflict and social engagement. The key characteristics of both types of methodology are summarised in Table 4.

Table 4 Characteristics of Rational Comprehensive Planning Contrasted with New Approaches to Problem Structuring (Adapted from Rosenhead, 1989: 12)

Characteristics of Rational Comprehensive Planning (Tactical Applications)	**New Approaches to Problem Structuring (Strategic Applications)**
1. Problem formulation in terms of a single objective and optimisation. Multiple objectives, if recognised, are subjected to trade-off on a common scale.	1. Non-optimising; seeks alternative solutions which are acceptable on separate dimensions, without trade-offs.
2. Overwhelming data demands, with consequent problems of distortion, data availability and data credibility.	2. Reduced data demands, achieved by greater integration of hard and soft data with social judgements.
3. Scientization and depoliticization, assumed consensus.	3. Simplicity and transparency, aimed at clarifying the terms of conflict.
4. People are treated as passive objects.	4. Conceptualises people as active subjects.
5. Assumption of a single decision maker with abstract objectives from which concrete actions can be deduced for implementation through a hierarchical chain of command.	5. Facilitates planning from the bottom-up.
6. Attempts to abolish future uncertainty, and pre-take future decisions.	6. Accepts uncertainty, and aims to keep options open for later resolution.

Rosenhead concentrates on the following approaches (1989: xii):

- Strategic Options Development and Analysis (SODA);
- Soft Systems Methodology (SSM);
- Strategic Choice, including the Analysis of Interconnected Decision Areas (AIDA);
- Robustness Analysis;
- Metagame Analysis;
- Hypergame Analysis.

He also acknowledges that a number of other decision structuring methods exist "which make a contribution in this area" (1989: xiii). Among those mentioned are:

- Decision Conferencing (a social process for using multi-criteria decision analysis with groups of key players and decision makers (see Section 4.3.3));
- The Analytic Hierarchy Process (AHP).

A number of these approaches to decision support that seek to "address the provision of appropriate elements of structure for strategic problem situations" are discussed here. Although AHP and the process of decision conferencing are not explored in depth in Rosenhead's publication, it is clear that the elements of the methodological difficulties which led to their development have similarities to the crisis that afflicted the OR community. The generic term used here to describe such emerging approaches is "Structuring Methods for Strategic Decision Support", which can be thought of as representative of an "alternative paradigm" in Rosenhead's terminology, which is contrasted with that of traditional approaches. This term is used here with reference to their usefulness in application to complex decision contexts. However, it must be emphasised that AHP and Decision Conferencing are very different approaches; they are theoretically distinct exemplars of a diverse range of normative, descriptive or prescriptive approaches. For example, SSM can be characterised as having a theoretically descriptive approach, similar to that of OR generally. By contrast, the multi-attribute utility theory used for decision conferences has its origins in normative utility theory and is conceptually distinct from the generally descriptive methodology of operational research.

In addition, Yolles (1999) has also provided a review of methods of enquiry for management systems, which includes an explanation of the origins of approaches referred to above. He posits that such methods can be characterised conceptually as lying on a continuum from "hard" to "soft" approaches (1999: 235). He questions whether it is useful to be overly concerned with these characteristics of management enquiry methods. He sees this in itself as an abstraction where both extremes reflect a reductionist worldview, "with positivism and a mechanistic view emerging in the 'hard' paradigm, and the social sciences attempting to use the methods of natural sciences to explain their objects of study" (Mayon-White, 1993: 41). In Figure 4, his view of the continuum of hard and soft approaches is mapped to show shifts in methodological approaches over time. The fuzzy values on the x-axis should be thought of as circular rather than a straight line, since the extremes of hard and soft approaches are defined as operating with a similarly deterministic outlook, while the central area defines "contrasting paradigms" of a "phenomenological" approach[4] (1999: 236). The diagram can be thought of in terms of a cylinder whose axis is parallel to the time axis, with the various ideas and methodological developments mapped along the surface.

The rest of this section provides an overview of the methods referred to by Rosenhead (1989) as providing a contribution to the new approach to strategic decision support. The methods I have referred to in this section as exemplars of the approach are:

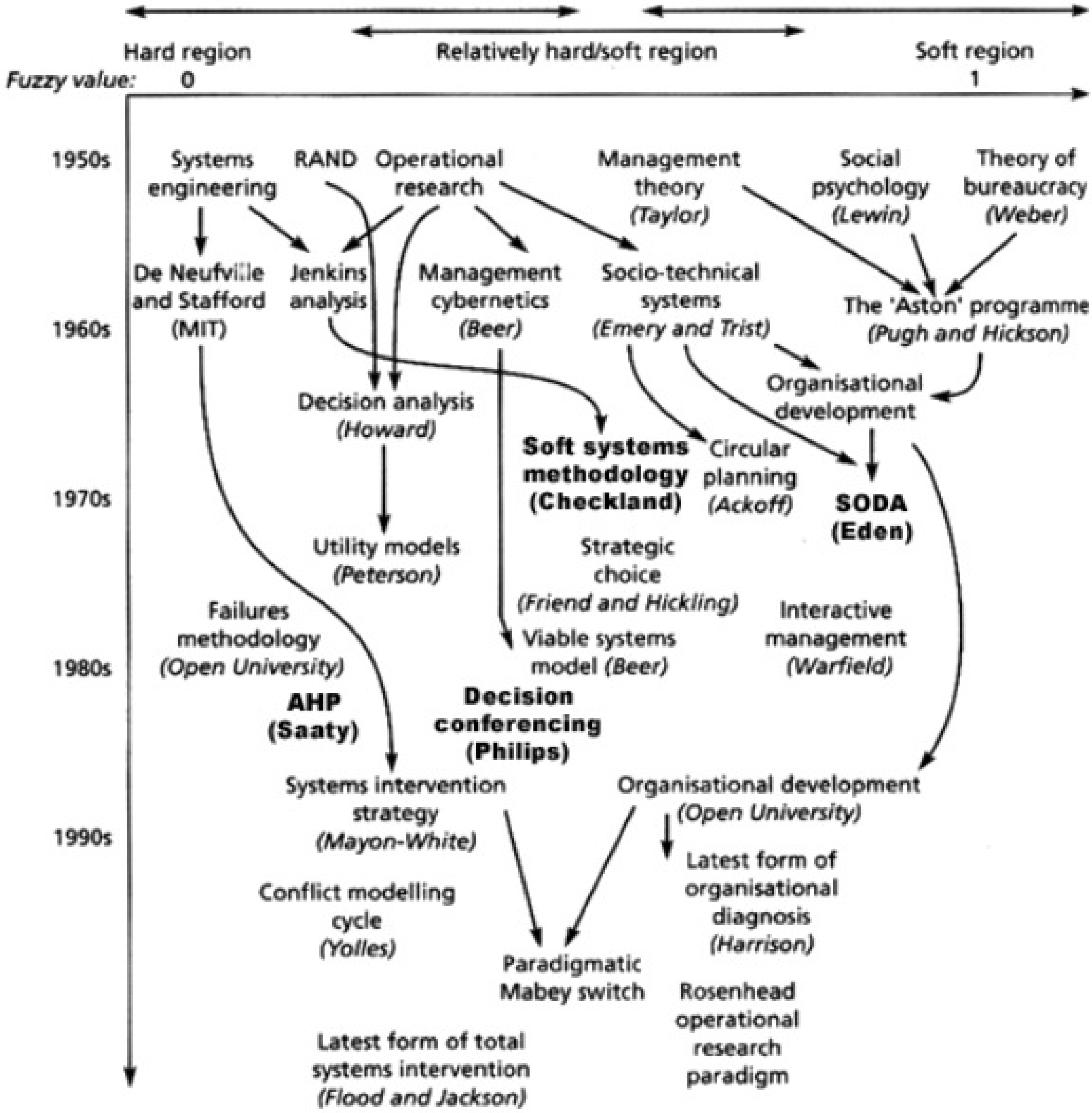
- Strategic Options Development and Analysis (SODA);
- Soft Systems Methodology (SSM);
- Decision Conferencing;
- Analytic Hierarchy Process (AHP).

In terms of Yolles' typology illustrated in Figure 4, they are listed in order of increasingly "hard" methodological characteristics, with SODA having the "softest" methodology and AHP the "hardest".

[4] This is a reference to phenomenalism, the philosophic theory that all knowledge springs from sense perceptions. This is a 20th century philosophical tradition, which benefited greatly from the contributions of the German philosophers Edmund Husserl and Martin Heidegger.

Figure 4: Paradigmatic Approaches to Explanation and Enquiry (Yolles, 1999: 236)

The methodological approaches in bold are those discussed later in this section[5].



[5] Saaty's Analytic Hierarchy Process was not included in Yolles' original review, but has been added here to illustrate the relative positioning of the methods discussed in this section.

4.3.1 Strategic Options Development and Analysis (SODA)

SODA is a method designed explicitly for working on complex problems. Eden describes it as "an approach which is designed to help OR consultants to help their clients work with messy problems" (1989: 21). He sees two essential skills as being relevant to the consultant wishing to use the method. Firstly, the practitioner should be an experienced facilitator who can enable processes involved in getting a team to work together effectively. Secondly, the consultant should be able to construct a model of "the content" that each member of the team wishes to address and be able to analyse that content effectively. Process and content management in the method are not considered separately, but reflexively inform the way each skill is used.

The objective is to manage the process by which the team working on a specific problem arrive at consensus for action, with commitment to that action (1989: 22). Success is measured by arriving at the point where people feel confident enough to take action. As Eden notes, "SODA's success cannot be measured by the rationality or optimality of the action portfolio alone." The focus is on "problem finishing" rather than "problem solving" (*ibid.*).

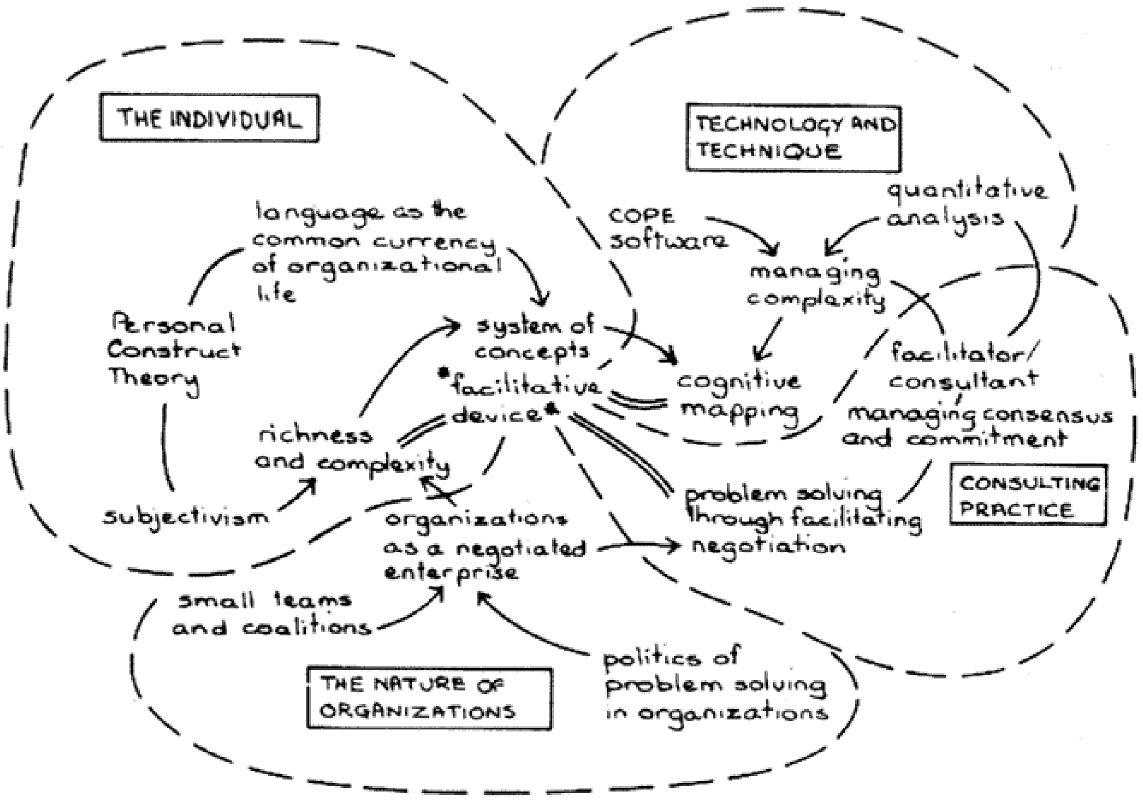
Eden proposes that a number of conditions will apply to situations where a SODA approach will be helpful. It is important to note that these conditions focus on the people involved in the process (the OR consultant and the client group) rather than the content of the problem to be solved. Eden states that in terms of personal characteristics, the OR consultant should:

- Be interested in practical aspects of social and cognitive psychology, tending to look for theories to help analyse tensions in the client team as they arise;
- Enjoy operating "on the hoof" rather than "in the backroom";
- Relate to a group of 3-10 people as the client, rather than conceptualising the whole organisation as the client;
- Be comfortable in using a contingent and cyclic approach to the problem, proceeding flexibly. This can be thought of as counter to a preference for using a linear approach towards a specified goal.

These characteristics are also important in determining the types of client group who are likely to find the SODA approach helpful. In particular, the client group should be seeking assistance with thinking through a situation faced, but should not expect that the consultant will act as an expert with respect to the content (1989: 23). The consultant facilitates the process of bringing together perspectives of a problem, analysing the content of the perspectives and arriving at agreement on taking action.

Four basic theoretical perspectives form the basis of SODA, which is described as a facilitative process. Figure 5 illustrates the perspectives, which concern the individual, the nature of organisations, consulting practice and the role of technology and technique. The technique is primarily informed by a subjectivist view of problem solving. Every member of the client group is characterised as having a subjective view of the problem. The wisdom and experience of the group is the source of content for the facilitation process, while the process is geared to harnessing this content in a way that allows progress towards action.

Figure 5 Theory and Concepts Guiding SODA (Eden, 1989:24)



Eden argues that there is no division between individual perceptions of the problem and the reality of the problem itself[6]. SODA is theoretically grounded in the work of Kelly (1955) on "The Theory of Personal Constructs" (Eden, 1989: 25). This is a cognitive theory, characterising people as continually striving to understand the world conceptually, in order to manage or control it. In this sense they are seen as active subjects. It follows that one of the key techniques used in SODA is a form of "cognitive mapping", which can be understood to have developed as a consequence of using the SODA approach (1989:26). The SODA approach uses language to create a model of ideas "that represent the way in which a person defines an issue" (1989:27). It is a network of ideas, linked by arrows to represent the way in which they may have implications for or give rise to one another.

A cognitive map of the issue would be derived for each member of the client team to illustrate how each team member conceptualises an issue. The next stage involves merging the maps to create a "strategic map" (1989: 33). The objective is to produce a facilitative device for negotiation of a way forward for the client group to take action with regard to the problem. When the strategic map has been created, the consultant needs to analyse the content and structure of the model to generate an agenda for the SODA workshop. This is the most important element of the facilitation process, and must address the aggregated data in a way that "does not lose any of the richness and detail of the individual cognitive maps" (1989: 36). The consultant should identify "emerging themes" and "core concepts" to use in the facilitation process. Computer software (COPE) has been designed to assist with this, but is not essential to the process.

[6] This again implies a phenomenological approach, as advocated by the work of Husserl and Heidegger.

At the workshop, the consultant needs to ensure that the participants are guided through the model created and can see how their individual contributions have contributed to the model, creating ownership. At the next stage, participants discuss the model and the consultant may elaborate the map further. It is usual for the workshop to identify opportunities for further work on the problem, such as financial modelling, statistical analysis or market research (1989:39). In this way, SODA does not replace more traditional OR methods, but provides a way of deciding which of them will be valuable in solving complex problems and a consensus among the client team regarding the overall approach required for problem solving.

4.3.2 Soft Systems Methodology (SSM)

Systems engineering was a method for "the selection of an appropriate means to achieve an end which is defined at the start [of an engineering research and development project] and thereafter is taken as given" (Checkland, 1989: 73). From systems engineering, an approach known as systems analysis emerged, bringing together theoretical principles from engineering and economics to enable decision-makers on major projects to solve operational problems. The approach can be characterised as "hard" and involves defining:

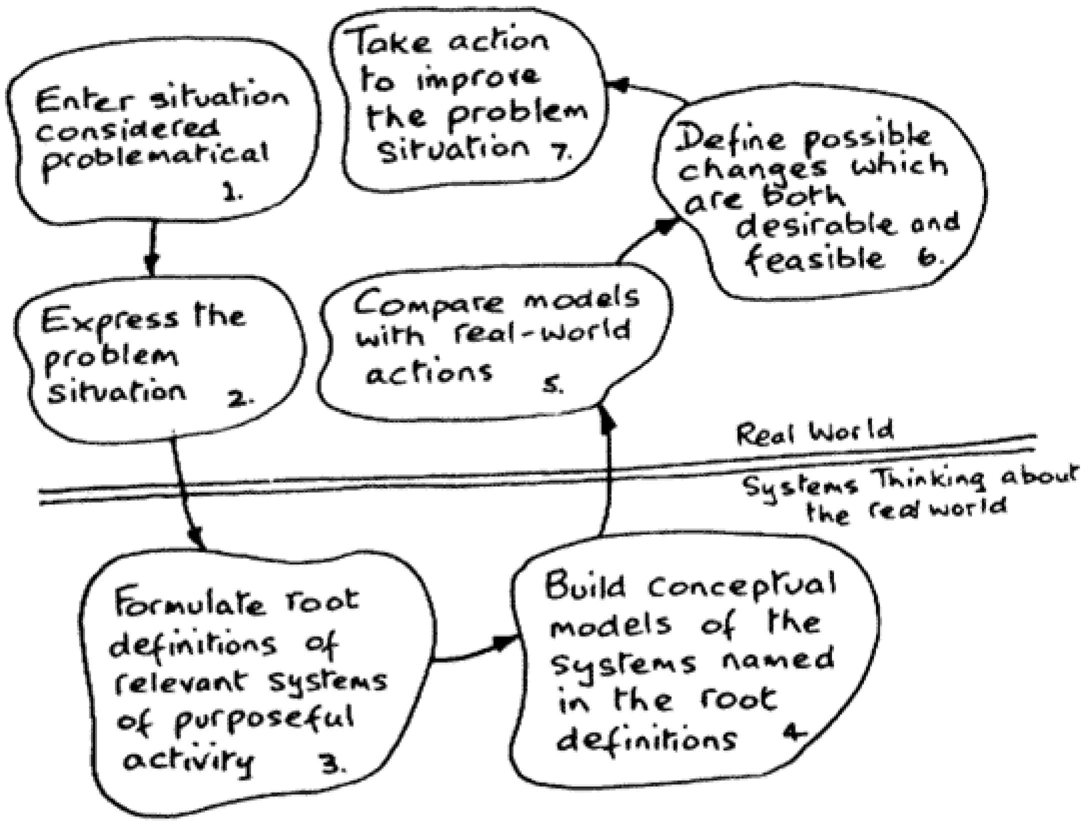
- An objective to be achieved;
- Different systems for achieving the objective
- Costs or resources required by each system;
- Models illustrating the interdependence of objectives, systems, resources and the environment;
- A criterion for choosing the preferred alternative.

SSM is an approach to problem solving which developed from this, to be applied where systems engineering/analysis failed because it was unable to address "the messy, changing, ill-defined problem situations with which managers have to cope in their day-to-day professional lives" (1989: 72). Checkland saw the difficulty in carefully defining an objective as the main reason for a new approach, because the objectives in messy situations are also problematic themselves. In other words, the assumption made by hard systems analysis that a problem will be well-structured meant that it could not be applied to many real management situations. As Checkland observed,

> […] for most managers […] both what to do and how to do it are problematical, and questions such as : What is the system? What are its objectives? ignore the fact that there will be a multiplicity of views on both, with alternative interpretations fighting it out on the basis not only of logic but also of power, politics, and personality. An approach which assumes these questions have been settled, and concentrates only on getting together a response, will pass by the problems of real life, applicable though it may be once a particular project has been decided upon.
>
> (1989: 75)

While systems engineering/ analysis is concerned with achieving objectives, SSM can be described as a system for learning. The essence of the method is to learn about a complex, human problem situation and leads to action to improve the situation which is regarded as sensible by those involved in it. The action stage need not mark the end of the use of the method unless that is seen as desirable. Action changes the problem situation and hence a cycle of analysis can continue. The method is generally made up of seven stages, but it is asserted that it is not necessary to "slavishly follow the sequence from Stage 1 to Stage 7" (1989: 82). Figure 6 illustrates the learning cycle for SSM.

Figure 6 The Learning Cycle for SSM (Checkland, 1989: 84)



Stages 1 and 2: Finding Out
This is carried out through three phases of analysis. The first analysis looks at the intervention in the subject matter and aims to identify who can fill the roles of the "client(s)" and "problem solver(s)" in the study. These roles are conceptualised as those causing the intervention to take place and those conducting the study respectively (1989: 85). The occupant(s) of the latter role then lists those who can be conceived of as "problem owners", which will generally include all those with an interest in the situation or who are likely to be affected by changes in it. The second analysis establishes the significant social roles in the situation, the norms of behaviour and how good or bad performance is evaluated in roles. This ensures that the culture of the problem situation is considered. The third analysis appraises the political situation by investigating how power is located and expressed in the situation. The three analyses will lead to a rich picture from which some systems of relevant to the problem situation can be derived.

Stage 3: Formulating a Root Definition
Root definitions are constructed by considering the elements of the mnemonic CATWOE (1989: 85). These elements can be described as follows:

Customer or those who would be the victims or beneficiaries of the purposeful activity;
Actors or those who would do the activities;
Transformation Process or the activity which changes a defined input into a defined output;
Weltanshauung or the view of the world that makes this definition meaningful;
Owner or those who could stop the activity;
Environmental Constraints or the constraints in the environment[7] that the system takes as given.

It is crucial that the transformation process is characterised correctly, since this will help enormously with the model building in Stage 4. The end point of this stage would be to arrive at a small number of well formulated root definitions based on the primary declared tasks but also based on specific issues related to the problem, which can be modelled as systems in the next stage of the process. An example of an issue based root definition might be "a system to resolve conflicts on resource use", if the organisation carries out a number of different tasks.

Stage 4: Building Conceptual Models
A conceptual model is created at this stage to describe the activities within the systems implied by the root definition. The activities are structured according to their logical dependency on each other. The language used to create the model is "all the verbs in English" (1989: 89). Once the system model has been created, a monitoring and control sub-system is added, to provide insight into the difficulties that may cause the system to fail. This is illustrated in Figure 7. Three types of failure are possible.

Effectiveness
Failure may be caused because the system is designed to carry out an activity, but the activity may not be the right thing to do.
Efficacy
Failure may be caused because the means of achieving the desired output will not work in practice.
Efficiency
Failure may be caused because the system uses an excessive quantity of resources in achieving the desired end.

The end point of this stage should be the creation of a "number of models of activity systems, some of them probably related hierarchically, each built according to a particular pure view of the world which is declared in the W of CATWOE" (1989:95).

Stage 5: Comparing Models and Reality
Four ways of comparing the model to reality have emerged (1989: 96). The first and least formalised approach is to record the differences between the model's created and current perceptions. The differences should then be appraised to determine if they are of importance. This approach is helpful if roles or strategies are an issue.

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[7] In this context, Checkland uses "environment" in the broadest sense to include any features of the system or its external context having an effect on the problem situation. This is close to the original (thermodynamic) use of the word in English. It includes any social, technical or economic factors, rather than describing the natural environment alone.

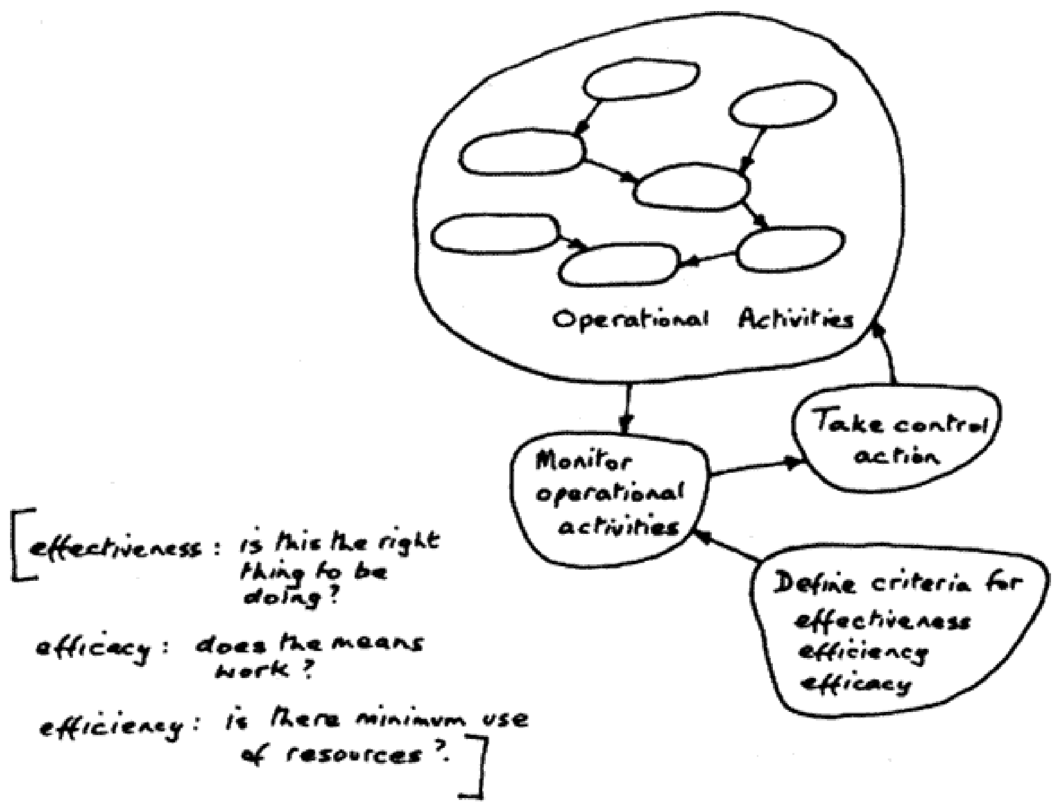
A second and more formal approach is required, which arises from the initial appraisal, if the issues are concerned with more detailed operational activities. Here, each system model is regarded as definition of a specific question regarding the activities, followed by a more detailed "Finding Out" process than has been conducting so far in Stages 1 and 2. "Ordered questioning" of activities is the usual manner of proceeding with this approach, such as "Does this happen in the real situation? How? By what criteria is it judged? Is it a subject of concern in the situation?" (*ibid.*).

A third type of comparison involves examining how the activity system will operate by writing a "scenario" to describe, with reference to the root definition for the system. Scenarios can then be compared with real experience of how similar examples have worked in the past in this situation, known to the people involved in the problem situation (*ibid.*).

The fourth and most formal method is to build a model of a relevant "part of reality" to compare with the system model (*ibid.*). This will involve following the structure of the systems model as closely as possible but by using a logical rather than a rich picture approach to modelling. The two models are then compared to indicate differences between the system model and the logical model. In practice, because logical models often express an intellectual abstraction of reality rather than the real world itself, it is often impossible to find a useful logical model to use for this process.

The output of this stage is the provision of a framework for debate about how to improve the problem situation, which is used in Stage 6 of the process.

Figure 7 General Structure of a Model of a Purposeful Activity System (Checkland, 1989: 91)



Stage 6: Defining Changes
This stage uses the differences between models and reality as the basis of discussion about how the problem situation can be improved. Checkland contrasts this approach with that of systems engineering, in that the models are not “designs” but are used to decide whether the real situation may be capable of changing to either more or less resemble the system model (1989: 97). What is required is an appraisal leading to suggestions for improvements which meet the criteria of being “systematically desirable” and “culturally feasible” (*ibid.*). The cultural feasibility of changes is often critical to whether progress will be made in real problem situations. Checkland cautions against approaches which underestimate the cultural aspects of the problem, as this often leads to the failure to implement recommended changes.

Stage 7: Taking Action
When agreement has been reached that a number of changes are “desirable and feasible”, the cycle of SSM is brought to a close by actions to implement the recommended changes. The problem situation should appear more well structured, but if it is still not clear how to implement the changes, further cycles of SSM can be used to examine this in more depth (1989:98).

SSM can thus be characterised as a method for learning about problem situations with a view to creating action to make positive changes to them. It has been used successfully in many disparate management situations in the public and private sector.

4.3.3 Decision Analysis
"Decision Analysis" is a currently used as a generic term used to describe a number of multi-criteria decision analysis (MCDA) techniques. It can also be used to describe a general approach to problem solving where a mixture of diverse criteria are used in appraising decision options against a set of objectives. This section charts the key theoretical developments and describes how MCDA has been elaborated to accommodate group decision-making activities, risk and uncertainty in assessments.

4.3.3.1 Development of Decision Analysis Theory

Frank Ramsey's paper on "Truth and probability", which was first presented to the Cambridge University Moral Sciences Club in 1926, has been regarded by many as the starting point for the development of modern approaches to decision analysis (Ramsey, 1931). He proposed an operational theory of decision-making based on the concepts of "judgmental probability" and “subjective utility”. These concepts have been applied in economics and statistics, as well as in philosophy[8]. However, it was only after the publication in 1944 of John von Neumann and Oskar Morgenstern’s classic text "The Theory of Games and Economic Behaviour" that utility theory began to be applied in modern decision theory. This work describes a normative[9] decision theory to demonstrate how individuals should rationally choose between a

[8] See "Frank Ramsey: a radio portrait, 'Better than the stars'" (found at http://www.dar.cam.ac.uk/~dhm11/RamseyLect.html) for a full account by DH Mellor of Ramsey's life and work. This is a slightly revised text based on a 1978 radio broadcast about Ramsey, forming one of a series of public lectures on Cambridge philosophers. The text is reprinted in DH Mellor (1995), "*F. P. Ramsey*", *Philosophy,* **70**, 243-262.
[9] This refers to decision research to determine how rational individuals should choose between options, rather than describing how individuals actually make decisions, which is descriptive.

number of options. The theory explained mathematically how to derive the subjective expected utility (SEU) values for options considered in decisions, where a rational individual would choose the option having the maximum SEU value (1944: 15-31 introduce the concept of utility). Much of this development had been anticipated in Ramsey's original work.

Another key development in the field was the publication of "The Foundations of Statistics" by Leonard Savage in 1954. The text followed Ramsey's "principle of coherence", which should be followed in order to make coherent choices, and provided the foundations of the theory of subjective probability. As Richard Jeffrey[10] (Princeton philosopher of probability) said of this:

> It was Savage's book, *The Foundations of Statistics*, that was published in 1954, that made subjectivism a respectable sort of doctrine for a serious statistician to maintain; and the remarkable thing is that Ramsey in this little paper to the Moral Sciences Club in 1926 had done all of that already, but somehow he wasn't speaking to the right audience or the audience wasn't prepared or something, but it was only sometime later that his ideas were rediscovered by people to whom the learned were attuned somehow or other.

Savage (1954) encapsulated Ramsey's ideas on coherence in a series of rules, as follows:

1. Either one has a preference or one is indifferent between alternatives i.e. $a \geq b$;
2. If a is more preferred than b and b is preferred more than c, so that $a>b$ and $b>c$, then $a>c$ (i.e. preferences are transitive);
3. There is dominance. If for 2 alternatives most aspects are the same but one alternative has 1 or more aspects which are better then this will be preferred;
4. "Sure thing" principle; the choice will be unaffected by what the alternatives have in common.

From these rules, it was possible to prove the following theorems:

1. Probabilities exist and these are logically consistent with coherent preferences;
2. Utilities exist and the numbers represent how much you value the consequences. They are composed of subjective values and a risk attribute;
3. For rational choice the alternative with the highest expected utility should be chosen.

These theorems can then be represented by:

i. Expected Utility $EU_i = \Sigma p_i U_{ij}$ for *i* options and *j* consequences; and
ii. The choice with the Max(EUi) should be chosen.

This demonstrates that the foundation for modern decision analysis is built on an axiomatic base. The main useful feature of the technique is that it enables one to be consistent with respect to preferences in decision making.

[10] Source as in footnote 8.

Following from this, the development of practical approaches to using decision theory to provide effective decision support provided a new direction for research in the discipline. The theorems were developed into an applied technology by the work of Howard Raiffa in his book 'Decision Analysis' in 1968, and later Ralph Keeney and Howard Raiffa in 1976 with 'Decisions with multiple objectives', who introduced some new assumptions.

Keeney and Raiffa assumed that preferences were independent, which can be represented by a third statement:

iii. Under this assumption the utility for any *j* th consequence can be obtained by taking the *Uj* for *k* criteria, i.e.

$Uj=\Sigma w_k U_{jk}$ where *w* is a weight

They also expanded the scope of decision analysis, so that the original theory relating to decision contexts involving a single decision-maker has been developed further to include group decisions involving multiple objectives, together with addressing uncertainties and risk.

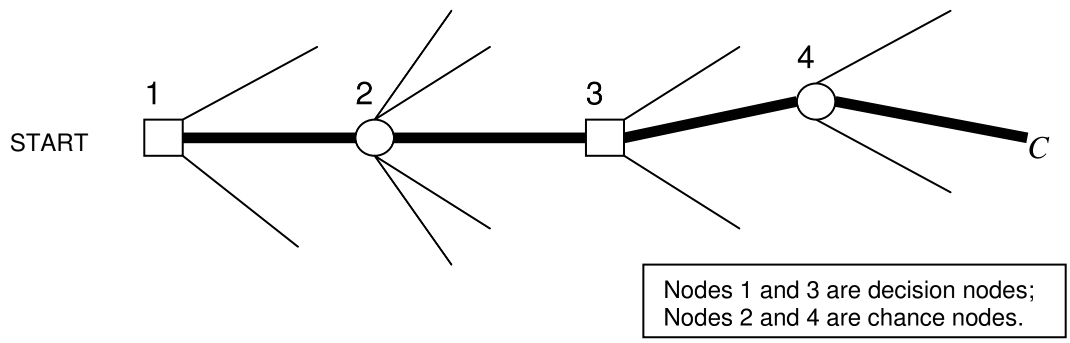
4.3.3.2 Developing Practical Approaches to MCDA

Keeney and Raiffa (1993)[11] have described decision analysis as a five step process as follows (*ibid.*: 5).

1. Pre-analysis
There is a unitary decision-maker who is undecided about the course of action to be taken on a problem. The problem has been identified and a number of viable alternatives have been identified.

2. Structural Analysis
The decision maker structures the problem qualitatively in terms of choices that can be made (either now or in the future) and assesses data collection requirements for the process. These features of the decision are summarised by a decision tree, as illustrated in Figure 8. The constructed decision tree will have nodes under direct control of the decision maker (decision nodes) and those which are not under full control (chance nodes).

Figure 8 A Schematic Form of a Decision Tree (Keeny and Raiffa, 1993: 5)



3. *Uncertainty Analysis*
The decision maker assigns probabilities to the branches from the chance nodes in the decision tree. The assignments are made on the basis of a mixture of different qualitative and quantitative methods, including the subjective judgement of the decision maker if this is necessary. These assignments are checked for internal consistency.

4. Utility or Value Analysis
The decision maker assigns utility values to consequences associated with paths through the tree. Figure 8 illustrates one possible path through a decision tree, from the start to point *C*. Each path is associated with a number of costs and benefits (e.g. economic, social, etc.) which either affect the decision maker or other considered individuals or situations identified as part of the decision problem. The cognitive impacts of each path of the tree are captured by associating a *consequence* with it that describes all the implications of that path. The preference for each consequence is then encoded by the decision maker as a cardinal utility number. The measurement reflects both the decision maker's ordinal rankings for different consequences (e.g. C' is preferred to C'' which is preferred to C''') and relative preferences for lotteries over these consequences.

As an example, Keeny and Raiffa considered a choice between a' and a'', translated into a choice between l' and l'', as illustrated in Figure 9. The decision maker assigns numbers to the consequences (such as u_i' to C_i') so that

$$(a' \text{ is preferred to } a'') \Leftrightarrow \left(\sum_{i=1}^{m} p'_i u'_i > \sum_{j=1}^{n} p''_j u''_j \right)$$

The assignment of such utility numbers to consequences must allow the maximisation of expected utility to be the appropriate criterion to determine the decision maker's optimal action.

5. Maximising Utility
Finally, the decision-maker calculates the best strategy, which is the one that maximises expected utility. The expected utility for each branch is found simply by assessing a probability and utility for each consequence. The product of the probability and utility values are then calculated for each consequence, and then summed to give an expected utility value for a whole course of action. This strategy is then the course of action having the highest expected utility, indicating what should be done at the start of the decision tree and what choices should be made at each decision node along the branch. This is usually calculated by using a computer program, using one of a range of techniques.

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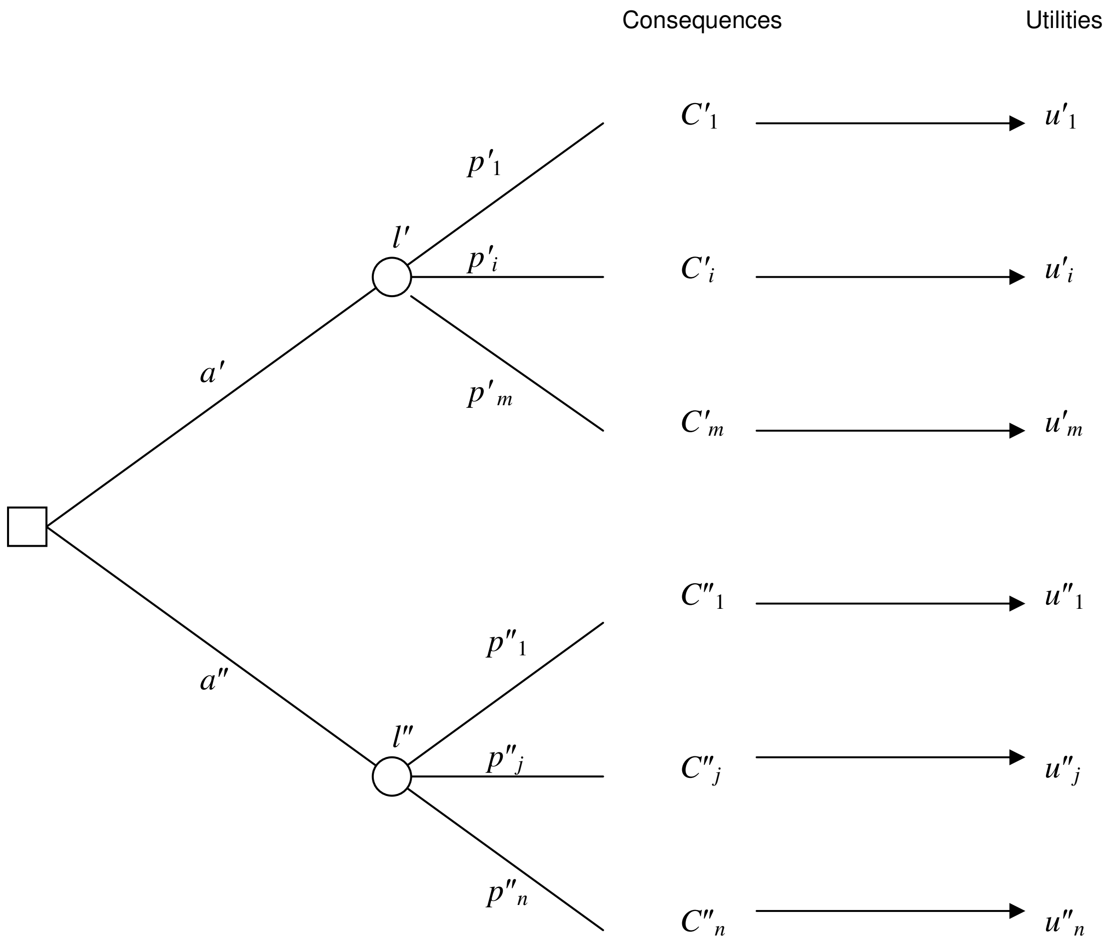
[11] Although Keeny and Raiffa's original work "Decisions with Multiple Objectives: Preferences and Value Trade-Offs" was published in 1976 by Wiley: New York, it was reprinted in 1993 by Cambridge University Press. This page numbers in this section refer to the reprinted version.

Figure 9 **A Choice Problem between Two Lotteries (Keeny and Raiffa, 1993: 7)**



Within this general framework, Keeny and Raiffa developed procedures for calculating "multi-attribute utilities", in a number of circumstances closer to decision making in real world scenarios. The main contribution that Keeny and Raiffa have made to the field is in demonstrating that in many cases, a simple linear additive model could be used as an approximation of von Neumann and Morganstern's SEU model, having the form:

$$S_i = w_1 s_{i1} + w_2 s_{i2} + \dots + w_n s_{in} = \sum_{j=1}^{n} w_j s_{ij}$$

where

S_i is the total score for each option
i is the option requiring evaluation
j is the criterion scored
sij is the preference score for each criterion
wj is the weight for each criterion
n is the number of criteria

This simplification had the effect of operationalising the SEU model, since von Neumann and Morgenstern did not demonstrate how individual utilities describing consequences could be evaluated (DETR, 2000: 116). Keeny and Raiffa also extended the general single attribute utility case to situations where the consequences are uncertain and/ or cannot be described in terms of a single attribute (e.g. money) (1993: 27).

A number of suggestions for using MCDA models to facilitate group decision-making are also made. In particular, Keeny and Raiffa discussed the role of sensitivity analyses in MCDA. Where agreement on valuation for certain criteria cannot be reached, sensitivity analysis should allow the group to see how the range affects the outcome. This is useful in that it is not necessary to reach consensus in order to explore the model. On the contrary, it provides a sound basis for arbitration and the possibility of compromise by discussion of the underlying assumptions and values at each stage of the development of the model (1993:541). This feature of MCDA is exploited fully in Phillips' Decision Conferencing process (section 4.3.3.3).

A manual has been published recently by the UK government to give advice on using multi-criteria analysis techniques in public policy decisions, with an emphasis on transport policy applications (DETR, 2000). It is intended to be complementary to various economic appraisal methods already in use and to utilise the types of data already collected, which is implied by its numerous references to the use of cost-benefit analysis techniques (for example, see page 9). However, later chapters (from six onwards) acknowledge that the extensive application of cost-benefit analysis to transport policy formulation has revealed the limitations of the approach and has raised the need to find "more comprehensive appraisal procedures" (2000: 74). MCDA is one of a number of techniques discussed which can contribute to a more robust basis for public policy decisions. In particular, the authors state that the "key motivation for using MCDA to assist government decision making is the need to accommodate formal analysis criteria that are not easily expressed in monetary terms, or which would be misleading to decision makers if monetised" (2000: 75). In this sense, the manual encourages the wider use of MCDA as an alternative to economic appraisal, in "an attempt to improve the clarity of the decision-making process" (*ibid*.). In particular, the authors' note that there is a need to ensure that there is a clear audit trail for policy decisions, which can be provided by the use of the MCDA approach. The steps involved in carrying out MCDA are shown in Table 5 below. However, these steps are often highly iterative in practice, rather than clearly ordered as shown.

Table 5 Detailed Steps in the Application of MCDA (DETR, 2000: 50)

1. Establish the decision context.
1.1 Establish aims of the MCDA, and identify decision makers and other key players.
1.2 Design the socio-technical system for conducting the MCDA.
1.3 Consider the context of the appraisal.

2. Identify the options to be appraised.

3. Identify objectives and criteria.
3.1 Identify criteria for assessing the consequences of each option.
3.2 Organise the criteria by clustering them under high-level and lower-level objectives in a hierarchy.

4. 'Scoring'. Assess the expected performance of each option against the criteria. Then assess the value associated with the consequences of each option for each criterion.
4.1 Describe the consequences of the options.
4.2 Score the options on the criteria.
4.3 Check the consistency of the scores on each criterion.

5. 'Weighting'. Assign weights for each of the criterion to reflect their relative importance to the decision.

6. Combine the weights and scores for each option to derive an overall value.
6.1 Calculate overall weighted scores at each level in the hierarchy.
6.2 Calculate overall weighted scores.

7. Examine the results.

8. Sensitivity analysis.
8.1 Conduct a sensitivity analysis: do other preferences or weights affect the overall ordering of the options?
8.2 Look at the advantage and disadvantages of selected options, and compare pairs of options.
8.3 Create possible new options that might be better than those originally considered.
8.4 Repeat the above steps until a 'requisite' model is obtained.

1 *Establishing the Decision Context*

Establishing the aims of the MCDA and identifying decision makers and other key players is the first step. The purpose of the analysis should be considered very carefully, since if this is incorrect then one can easily provide an exemplary analysis of the wrong problem, rendering the outputs redundant. Although the objectives may change as new issues are raised during the analysis, a degree of clarity in the initial stages assists with structuring tasks and maintaining momentum.

A "key player" is defined as "anyone who can make a useful and significant contribution to the MCDA" (2000: 51). They are chosen to represent a variety of perspectives on the subject of the analysis. A perspective of particular importance is that of the decision maker(s), referred to as "stakeholders" (*ibid*.). They are referred to as such because they have an investment in the consequences of any decision made. Even if they do not physically participate in the MCDA, their values should be represented by one or more participants. It is important to note that the analysis should never be limited solely to stakeholders views. Other key players will participate because they have knowledge or expertise that is relevant to the subject of the analysis. The identification of participants and the level of their involvement in the analysis is an important consideration in the design of the MCDA.

It is important to consider and establish a mechanism for the stakeholders and key players to contribute to the MCDA. Although a typical approach to problem solving in governmental workgroups is to "hold a series of meetings punctuated in between by staff work, continuing until the task is finished", it is claimed that a number of different social processes could promote a more efficient approach (2000: 52). Among these, the use of "facilitated workshops" is recommended, involving a group of stakeholders and key players, an experienced, impartial facilitator and the creation of a computer model to reflect the group's thinking about the problem "on the spot" (*ibid.*). This is also known as decision conferencing (Phillips, 1989). More details about this generic approach are given in section 4.3.3.3.

2 Identifying Options for Appraisal

Although the MCDA may or may not begin with a set of predetermined options, it is important that this is not treated as a selection between given options. As the analysis progresses, it is extremely important that there should be the possibility "of modifying or adding to the options" (DETR, 2000: 55). This is crucial because new alternatives are often generated when there is a better understanding of the decision objectives. In this sense, the process is both dynamic and creative. Other common errors include analysing only one option as if it were the only possible alternative, or neglecting to include an option reflecting the current situation if no action were taken.

3 Identify Objectives and Criteria

Assessment of the options requires that attention is paid to the consequences of implementing the options. Consequences achieve a number of objectives referred to as criteria (or attributes), which are specific and capable of measurement. Criteria are the described as the "children" of higher-level "parent" objectives (2000: 55). For instance, in choosing between two cars, one might have a higher-level objective of reducing costs to a minimum, but this may be broken down into, for example, the cost price of the car, a number of running costs and expected fuel costs as criteria. The running costs and expected fuel costs could then be disaggregated further into lower-level criteria such as insurance costs, fuel type and efficiency to suit the context of the decision.

A useful question to ask of the group when suggestions for criteria are made is "why do you care about that?" This enables a distinction to be made between "means" and "ends" objectives. When there is nothing more to be said, an "end" objective has been reached which is a fundamental criterion in the decision (2000: 55). Essentially, this is the point at which the particular attribute under discussion cannot be disaggregated into further lower-level attributes.

Criteria express the way in which the options under consideration create value for the key players or stakeholders. The nature of the problem itself will determine how the criteria are generated in the process. If the task is to evaluate a number of given options, then a bottom-up approach will be a way of determining how the options differ from one another in ways that are important. Conversely, a top-down approach will elicit information relating to the overall purpose or objectives to be satisfied.

In the case of government departments, the manual likens them to "visionary companies" in that they exist to create "non-financial value" as well as promoting budgetary efficiency (2000: 57). It is entirely consistent with this view that "identifying criteria requires considering the underlying reasons for the organisation's existence, and the core values that the organisation serves" (*ibid.*). It follows that methods of analysis that are unable to capture such non-financial criteria with clarity or that risk misleading decision makers (such as cost-benefit analysis) should have no place in public policy decision processes.

The criteria must then be organised under higher and lower level objectives in a hierarchy. The very top objective represents the overall result, with the most important trade off between objectives occurring at the next level down. This trade off is often between costs and benefits at this level, but need not be and is dependent on the nature of the decision analysed and its context. Other alternatives for top level trade offs include risks versus benefits, benefits to consumers versus benefits to suppliers, long term benefits versus short term benefits, and so on. The subsequent lower levels will disaggregate the objectives further and further until the bottom of the hierarchy is reached which is comprised exclusively of fundamental criteria. This hierarchy is usually referred to as a "value tree" (2000: 57). Organising objectives in the value tree helps to make conflicting objectives explicit and usually leads to a better definition of objectives and fundamental criteria.

4 Scoring

At this stage, it is important to describe the consequences for each alternative examined in the analysis. It may be necessary for complex problems involving a value tree to structure a separate consequence table for each option, in a similar fashion to the structure of the value tree, which accounts for each criterion involved in the decision.

The scoring process is deceptively simple. For each of the fundamental decision criteria regardless of the units, the scores are reduced to scales which indicate the strength of preference for the consequences associated with the options relative to one another on a preference scale. Different types of preference scales may be used, but it is most common to use a relative preference scale.

In using a relative preference scale, the top of the preference scale is typically assigned a preference value of 100 and refers to the consequences associated with the most preferred option. The bottom of the scale is assigned a preference value of 0 and refers to the consequences associated with the least preferred option. The remaining options are then scored relative to these two options so that the differences in the numbers reflect the strength of preferences for the consequences. The kind of judgement required for this process is fairly difficult. For example, if option 1 will cost £40000 per annum to implement (preference value of 100) but option 2 costs £50000 and a third option costs £60000 (preference value of 0) a score must be elicited for option 2. This requires a judgement concerning how much more onerous the loss of £10000 from the organisation budget is than the benefit of having an extra £10000 to spend, to allow it to be positioned on the preference scale. Is the loss of the money 5 times worse than having the benefit of spare capacity, twice as bad or twenty times as bad? This sort of judgement is required to generate the relative scores required in MCDA. The scores must also be checked for consistency as part of the scoring process, to ensure that relative preferences are reflected with accuracy.

Several iterations are usually required to ensure consistency within and between criteria.

5 Weighting

The weight on a criterion "reflects both the range of difference of the options, and how much that difference matters" to the group (2000: 62). In the example above, the difference between the top and bottom of the preference scale is £20000. A judgement is required as to whether this is a significant factor in evaluating the options in the analysis. Although the cost of the options is generally agreed to be an important criterion, it may be that this difference is not seen as a significant factor in the decision process by the group. On the other hand, if the benefits of saving an additional £20000 are thought to be significant, the cost will be weighted more heavily in the MCDA.

The main method used for determining weights for criteria scores is known as swing weighting. The criterion having the biggest swing in preference between the top (100) and the bottom (0) of the preference scale is identified. Where there are many criteria, this is usually done by creating a shortlist of criteria and then comparing the criteria in pairs to determine which of the criteria is considered to have the largest swing in preference. This criterion is then assigned a value of 100, and the other options are compared with it in a four stage process (2000: 63). First, all the participants in isolation are asked to come up with a weight for the second criterion in relation to the first. The participants then reveal their assigned weights to the group and results are recorded as a frequency distribution. The group members responsible for the highest and lowest assigned weightings are then asked to explain their reasoning for doing so. After a group discussion, a subset of the group are then asked to make the final choice of a weighting to apply to the criterion in the model. The subset is usually made up of the decision maker(s) and other participants in the group with a sufficiently broad view of the subject matter to appreciate where potential trade offs may occur between criteria.

The process allows all group participants independently to articulate their own view initially of the weighting to be applied to a criterion. The decision maker(s) are also able to be involved directly in the weighting process, which is proper since they will ultimately bear accountability for any decision made following the analysis. This is a strength of using MCDA with a group, since although all participants are allowed to express their viewpoints in the process, the decision maker(s) are involved in and retain responsibility for the decision problem for which they will ultimately be held accountable. In this sense it is fair, because key players and stakeholders are able to discuss their view of the problem, while the decision maker(s) are not coerced into weighting criteria in a way that conflicts with their own judgement. In this sense MCDA can be considered to be procedurally fair. It is often the case that agreement is not reached in the group about the weighting to be applied to particular criteria. In this case, then a number of sets of weighting can be taken "forward in parallel, for agreement on choice of options can sometimes be agreed even without agreement on weights" (2000: 63). These different sets of weightings can be used to model the decision problem to ascertain whether there is any difference in preferred option and to highlight criteria on which compromises must be reached among participants. This indicates some of the types of sensitivity analysis to be carried out later in the process.

6 Calculating Weighted Scores

The overall weighted scores are calculated for each level in the hierarchy of the value tree and overall scores for each option are generated. Provided that one precondition is met, this can be done using a simple linear additive model, described earlier as Keeny and Raiffa's operational approximation of von Neumann and Morganstern's SEU model (p34).

$$S_i = w_1 s_{i1} + w_2 s_{i2} + \ldots + w_n s_{in} = \sum_{j=1}^{n} w_j s_{ij}$$

where

S_i is the total score for each option
i is the option requiring evaluation
j is the criterion scored
sij is the preference score for each criterion
wj is the weight for each criterion
n is the number of criteria

The condition is that all the criteria must be "mutually preference independent" (2000: 64), or that the preference scores for each criterion must not be affected by the scores for other criteria. The failure of criteria to satisfy this condition is usually found during the scoring phase, because the assessor will see that it is impossible to score a particular criterion without having already calculated a score for other criteria. This often happens because "double counting" has occurred, which occurs when two criteria have been elicited that sound different but are actually describing the same attribute (*ibid.*). This is indicative of a need to combine the criteria into one criterion covering both interpretations. In the rarer cases that this approach is not possible, then more advanced and mathematically complex modelling may be required to calculate weighted scores for the options.

Public sector decisions are very susceptible to double counting especially when benefits with a distributive effect are involved, such as the effects of introducing tax cuts on different parts of the population. However, this is usually detected by applying the test of "mutually preference independent" to criteria. Judgements about whether double counting has occurred are unlikely to be made on a purely objective basis, as it will often depend on "the values that the organisation brings to the appraisal" (2000: 39). The facilitator will assist the group in making the changes to either the criteria (or rarely requesting that the analyst should use a more complex model) so that the problem can be overcome.

7 Examine the Results and Conduct Sensitivity Analysis

The initial examination of the results usually involves a consideration of the total preference scores, plus two-dimensional plots to show the main trade-offs made in the decision between objectives (2000: 66). For example, if costs and benefits are the next level down from the top in the value tree, a graph of the scores for each option plotted against the two objectives will give an indication of which options represent good value for money. The "outer surface" of the plot shows which options "dominate", in this case indicating cost-effective options (*ibid.*).

Sensitivity analysis explores the data deficiencies and disagreements about qualitative inputs to the model to see if there is an effect on the overall preferences for decision options. Weighting is often a contentious area that will require sensitivity analysis. If there is little difference in the ordering of preferences for options, then agreement can be reached easily without any consensus on inputs or weighting being necessary. It can also be demonstrated that where the same few options are always preferred but in a slightly different order, then perhaps agreements can be reached amongst the stakeholders that one of these options could be recommended, even if it is not their first choice. Thus sensitivity analysis becomes a useful means for resolving conflicts between stakeholders and key players.

The relative advantages and disadvantages of options should also be compared, in order to illustrate areas for improvement. This can take the form of generating new options that were not originally intended, which can then be evaluated alongside original options against the same criteria by further analysis. In the example of a main trade off of costs against benefits, the costs might be reduced by reducing benefits that were considered unimportant in the analysis.

These steps are repeated until a "requisite" model is obtained for the decision (2000: 68). This is one which is just informative enough to resolve the decision problem addressed. This saves considerable time which would potentially be spent collecting elaborate data and constructing models that have no relevance to the key objectives addressed by the decision problem. A feature of MCDA models is that they are "remarkably insensitive to many scores and weights", which is often demonstrated during sensitivity analysis (2000: 69). However, most people involved in an MCDA often find the "rough and ready" nature of inputs difficult to accept until they have seen the sensitivity analysis phase of MCDA for themselves. This may result from most people's prior experience with models where data inputs are very sensitive to precision. However, MCDA models are relatively insensitive to the precision of data inputs for two reasons:

- Changes in scores for individual criteria often have very small effects on the total preference, because the scores for other criteria will minimise the effect of changes;
- Scores for many criteria show a high degree of statistical correlation, so the weights on those correlated criteria may be distributed among them in any way without affecting the total preference greatly.

This combination of factors may have the effect of rendering sensitivity of the total preferences rather insensitive to changes in either data quality or weighting for an individual criterion. This is why it has been observed that as a group or organisation gains experience of using MCDA, the models tend to become "simpler and more requisite" (2000: 69).

Finally, the facilitator will assist the group in summarising their key recommendations, including their preferred option. If agreement has not been reached on a preferred option, effort will focus on agreeing ways to resolve differences of opinion between stakeholders. This can include further analysis, operational activities, further modelling or data collection or arbitration. The outcome of the MCDA should always include an action plan to implement recommendations.

4.3.3.3 The Decision Conferencing Process: an Approach to Designing the Socio-Technical System for Using MCDA

Decision conferencing is a specific process used to structure decisions as a form of "social analysis" using the MCDA technique, comprised of "an intensive, two-day problem-solving session attended by a group of people concerned about a complex issue with which an organisation is faced" (Phillips, 1989). It represents one possible approach to "designing the socio-technical system" for conducting the MCDA (referred to in step 1.2 of Table 5.5). This involves the immediate creation of a computer model, incorporating the different viewpoints of the participants. During the process of refining the model and testing the assumptions made for sensitivity, the process engenders a common understanding of the dimensions of the problem and ideally, agreement on the way forward. In this sense, the process of carrying out the analysis matters as much as the outcome.

The objectives of the decision conference will be to generate a shared understanding of the issues, a sense of common purpose and a way forward. This does not imply that consensus is a prerequisite: the great strength of this methodology is that it tolerates diversity of views whilst also demonstrating to the delegates that there is a shared awareness and comprehension of the problem situation.

The group is selected on the basis that it has representation of the diverse stakeholder views on the decision issue. The group will be made up of key players, which may not necessarily be all of the stakeholders. The conference is assisted in the process by at least two people external to the organisation: a decision analyst and a facilitator. Both should be experienced in working with groups. The facilitator assists the group to structure the decision and encourages creative thinking to identify key issues, problem modelling and interpretation of results. The analyst builds the computer model and assists the facilitator (Phillips, 1989: 95).

The model created is based on decision theory and the type of model generated depends largely on the type of decision to be made. The dimensions of the problem relevant to the choice of model tend to be dominated by the extent of uncertainty in the decision process and whether there are single or multiple objectives in making the decision.

The agenda will usually be flexible so that creative thinking is not stifled. The aims will be to:

- Establish the context;
- Explore the issues;
- Create a model to aid thinking;
- Explore the model using sensitivity analyses to validate findings;
- Develop shared understanding and commitment.

Decision conferences can be used for a variety of different decision contexts; reported examples range from resolving siting problems for nuclear waste facilities to formulating corporate strategies. It has proved to be a powerful and flexible method of decision support. Although Phillips notes that "every decision conference is different" (1989: 96), a number of stages are commonly observed.

Firstly, an attempt is made to formulate the nature of the problem and to establish the context within which the decision problem exists. This stage is especially useful where problems are nebulous or alternative courses of action involve the consideration of conflicting objectives. The facilitator will elicit information from the group about the problem and assist them in defining the important aspects of the problem situation. Once the nature of the problem has been formulated, a structural representation of the problem is created.

The facilitator then uses the group to provide content to allow a model describing the group's thinking about the problem to be constructed. This will involve quantitative data and qualitative value judgements concerning the relative performance of alternatives against a set of objectives elicited from the group. The model can be demonstrated to the group by using a projector to illustrate the results generated. The initial results can then be tested for sensitivity by changing assumptions and hence data inputs in the model. In the final stages and after many iterations, the group can use the experience gained in the modelling process to summarise key issues and conclusions. A list of actions is compiled as the last stage of the process. This enables the participants to begin implementing the preferred alternative immediately when they return to normal duties.

4.3.4 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) developed by Saaty (1980), is a method of converting subjective assessments of relative importance into a set of scores or weights. The method has been widely used in many applications (e.g. Ong et al., 2001). The first stage of carrying out the AHP is a problem structuring exercise, to arrive at a set of criteria by which the validity of a decision will be judged. Sources of data to quantify the magnitude of the criteria will also be found so that the criteria can be quantified, either qualitatively or quantitatively. This process may be carried out by a single decision maker or by a group of key stakeholders. The main source of data for the AHP is a pairwise comparison of decision criteria to arrive at relative weights for them within the decision context and performance scores for decision options. This weighting process involves the use of a nine-point scale to rate the relative importance of two decision criteria against one another. Table 6 illustrates the scale used in the AHP to arrive at weights for the criteria.

Table 6 Saaty's Scale for Pairwise Comparisons of Decision Criteria (DETR,2000: 124)

How Important is Criterion A Relative to Criterion B?	Assigned Preference Index*
Equally Important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Overwhelmingly more important	9

*Where 2, 4, 6 and 8 represent intermediate values to reflect judgements falling between the 5 main points on the preference scale.

The increasing numerical preference index assigned represents the increasing importance assigned to criterion A over criterion B in the decision process by each decision maker. If criterion B is considered to be more important than A, a reciprocal value is assigned. For example, if B is considered to overwhelmingly more important than A in this particular decision, a value of $^1/_9$ is assigned to A relative to B.

A matrix is then drawn up to illustrate the relative preferences for the criteria involved in the decision, consisting of n x n possible pairwise comparisons for n criteria. However, because consistency in judgements is assumed in evaluating weightings for any pair of criteria and criteria will rank equally (value of one) when compared with themselves, for n criteria it is only necessary to make $^1/_2 n(n\text{-}1)$ comparisons.

Weights are then estimated by one of a number of different methods. While there is complete consistency in the numerical judgements made about any pair of criteria in the matrix (which will have a reciprocal relationship with each other), there is not necessarily consistency in the judgements made between pairs of criteria in the assessment (2000: 125). Saaty's original method involves calculating weights as the elements in the maximum eigenvalue of the matrix (2000: 125). This involves complicated matrix algebra that in practice is usually carried out using specialist computer software. In simple terms, this can be thought of as a process of obtaining an "average" of all the ways of thinking about a set of alternatives. The equation for calculating the matrix's eigenvector is

$$\text{Eigenvector} = \lim A^k e / e^T A^k e$$

where k>infinity
A = Matrix
e = (1, 1…….., 1)

A simpler alternative is to calculate the geometric mean of each row in the matrix, then total the geometric means and finally normalise each of the geometric means by dividing by the total computed. Although the figures obtained will not be exactly the same, they are usually very near to the values calculated by the more complicated eigenvector method. For this reason, the simplified method is often used.

A full AHP also uses pairwise comparisons to determine relative performance scores for each option on each decision criterion. This involves a further pairwise comparison process where the relative importance of the performances of pairs of alternatives are considered, to determine their contribution towards meeting each of the decision criteria. Using the same nine-point scale, if there are m decision options and n criteria, then this will require n separate m x m matrices to be analysed (2000: 126).

Finally, when the weights and scores have been determined, an overall evaluation for each of the options considered can be calculated by using a linear additive model (as used in MCDA methods discussed in Section 4.3.3). All of these scores will lie in the range zero to one. The option with the largest score will be the most preferred in this particular decision context, but the value will be tested for sensitivity to make sure that the analysis is valid.

AHP has been criticised by decision analysts for a number of reasons. The most serious of these is the way in which the method handles criteria weights, which can sometimes cause reversals in ranking (Perez, 1995), when new options are introduced or options are removed, changing the relative ranking of some of the original or remaining options. This is obviously unsatisfactory and happens because the weight of each criterion is independent of the evaluations of the options over this criterion (*ibid.*: 1091), but is often obvious and easily remedied. Other problems cited include the following (DETR, 2000: 126-127):

- Because weights are elicited for criteria before measurement scales are set, the decision-maker has to make judgements about their relative importance before knowing what their importance is to the decision under consideration (e.g. if the magnitude of the criterion is similar in each option, it will have little relevance to the decision);
- The 1-9 scale may be internally inconsistent in ranking e.g. if A scores 3 relative to B and 5 relative to C, the 1-9 scale means that a consistent ranking of C (15) is impossible;
- There is no theoretical basis for the link between the descriptions used in the nine-point scale and the corresponding verbal descriptions given by the decision-maker;
- It is a matter of considerable debate in the decision analysis community whether the established principles involved in AHP are actually capable of being tested empirically for validity.

Even with these widely acknowledged and serious limitations, AHP has often proved a useful tool for decision structuring. For this reason, some decision analysts have proposed that it is only necessary to determine which decision contexts are suitable for the use of the method (Perez, 1995). Others have attempted to adapt the AHP to retain its benefits while avoiding some of the difficulties. The best known of these is REMBRANDT, which uses a logarithmic rather than nine point preference scale and replaces the eigenvector method for calculating estimated weights with a geometric mean calculation for estimating weights and scores from the matrices of pairwise comparisons (2000: 127).

4.3.5 Summary: Suitability of Methods for Environmental Policy Decisions

In a similar way to the field of risk assessment and management, OR is a changing discipline which is moving away from a purely analytical methodology. This evolution in approach is mirrored across a number of related disciplines which have been described in the past as "conventional methods for rational analysis" (Rosenhead, 1989: 1). This methodological development is characterised by a growth in available structuring methods for strategic decision support, which are able to address complexity in the decision process, and are able to accommodate group decision-making activity involving divergent frames of reference and potential conflict. A number of the methods referred to by Rosenhead would also be suitable for use in environmental policy decisions for this reason. SODA and SSM are extremely useful methods for structuring problems where objectives are either unknown or nebulous. Using MCDA through the process of decision conferencing can be helpful in this respect, but may also be used to evaluate existing options where a decision context is better defined. AHP is of more use where the decision to be made is known with clarity and the objectives to be addressed have been predetermined: it is not necessarily clear that it is useful for addressing the more complex, strategic contexts which are commonplace for environmental decisions. In this sense, the methods can be characterised as increasing in “hard” and decreasing in “soft” character, in Yolles terminology (see Figure 4).

To date, of the four methods described above, it is fair to say that AHP has received the most attention in environmental decision-making (see for example, Ong et al, 2001). Some of the practical and theoretical difficulties with this approach have been described in Section 4.3.4. It is difficult to ascertain why this technique has been utilised in preference to the other methods described, which are more firmly grounded theoretically and pay more attention to the social dynamics of complex decision contexts[12]. Of the two multi-criteria analysis methods described, wider use of MCDA through the process of decision conferencing would appear to be a fertile area for future development. This is due to the great potential for creating a shared sense of purpose with respect to the outcome of a decision amongst the participating stakeholders, without the need to impose consensus. The potential for increasing trust amongst the participants and learning about the reasons for participants' views with respect to the decision are compelling reasons for its use, especially where communication has been historically difficult or values are important.

The dynamic and highly iterative nature of the method allows creative thinking to flourish, and this useful feature should not be underestimated. For example, the method can allow the generation of new decision options during the process of exploring advantages and disadvantages of the current options, which has proved extremely useful in practical applications. In issues of public policy, the transparency of the process also allows a full audit trail for the deliberations of the group to be made available, including detailed explanations of the reasoning and value judgements behind the final decision. This is urgently required since environmental decision-makers are increasingly held to account for their policy decisions, as legislation increasingly drives the public freedom of information agenda. For these reasons, wider use of MCDA through the process of decision conferencing would be extremely useful for structuring environmental policy decisions in the public arena and formulating strategies for environmental protection.

[12] The more widespread use of AHP may be attributable in part to the free availability of information on how to apply the methodology in practice. This allows applications in problem structuring and decision making, even by those without any prior experience. In addition to a wealth of published research, software and publications are also available on the Internet. By contrast, there is little practical published information describing how to apply the alternative methodologies examined in this section. This renders the use of these alternatives rather difficult, without employing skilled consultants to undertake such studies.

4.4 Life Cycle Assessment

Life Cycle Assessment (LCA) is a relatively new environmental management tool. The first documented LCA was carried out by Harry Teasley jr. for the Coca-Cola Company in 1969, in order to compare the impacts of different beverage containers on the environment. Since the 1980s, interest in the tool has been revived as societal interest in reducing environmental impacts from human activities increased. There are many companies and organisations that wish to incorporate it in one form or another into their environmental management systems and policies.

LCA is a tool used to evaluate the environmental effects of a product, service or activity (referred to hereafter as "the product system"). LCA is a powerful method of assessment and its usefulness lies in the ability to include impacts occurring upstream and downstream from the product system. LCA provides a formal systems analysis framework for "life cycle thinking"; that is, documenting the environmental impacts of a product system from the extraction of raw materials, manufacture, retailing, use and through to their final disposal.

4.4.1 Developments in LCA Methodology

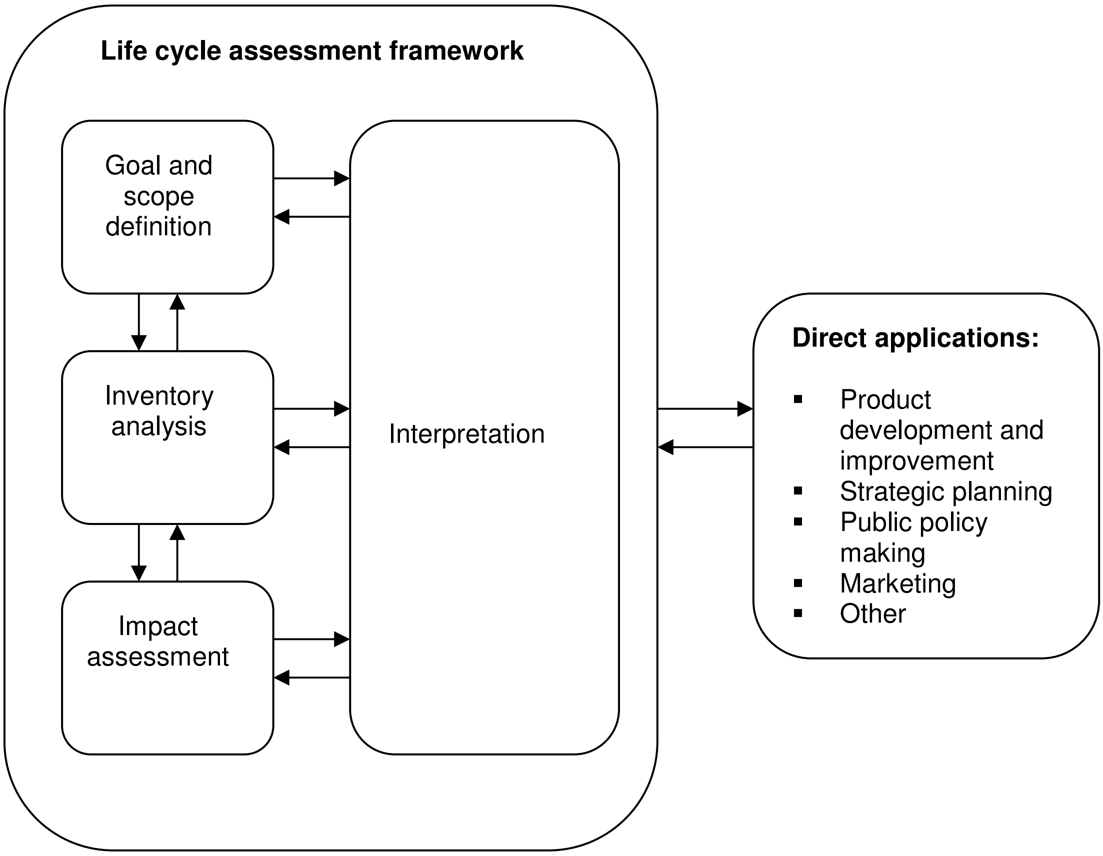
The development of LCA over the past ten years has seen much effort to create a standard methodological framework for its use. This culminated in the development of standards by the International Organisation for Standardisation (ISO) for conducting LCA studies can be seen as a response to difficulties concerning a lack of consistency in approach, addressing the need to ensure that LCA studies are viewed as scientifically and procedurally robust. Organisations whose input to the development of this framework has been vital include SETAC (Society for Environmental Toxicology and Chemistry), SPOLD (Society for the Promotion of Life Cycle Development) and the European Union (primarily by the funding of a number of high profile projects to further research in this area).

The framework set out in the ISO standards distinguishes four different phases that must be followed in an LCA. These standards have since been adopted without modification by the European Committee for Standardisation (CEN) and the British Standards Institution (BSi). The general framework within which these phases are located is outlined in BS EN ISO 14040 (BSi, 1997). These phases, whilst they appear to be distinct, are in fact highly iterative, as illustrated in Figure 10. Broadly, the phases are known as:

- Goal Definition and Scoping (BS EN ISO 14041 (BSi, 1998));
  This concerns the determination of the intended application of the results, the reasons for carrying out the study and to whom the results will be communicated. The choice of product systems to be analysed will also be made at this stage.
- Inventory Analysis (BS EN ISO 14041 (BSi, 1998));
  This involves the collection of data about the product systems investigated and the quantification of the relevant material and energy inputs and outputs for each of them. Data collection is influenced by the goal and scope of the study.
- Impact assessment (BS EN ISO 14042 (BSi, 2000A));
  In general, this involves evaluating the inventory of inputs and outputs to the product systems in terms of their potential environmental impact. The choice of impacts evaluated and the methodologies used depend on the goal and scope of the study.
- Interpretation (BS EN ISO 14043 (BSi, 2000B)).

In this phase, the findings from the inventory analysis and the impact assessments are combined to allow conclusions to be drawn and recommendations to be made. This usually takes into account any sensitivity analyses carried out. It may sometimes involve an iterative process where the scope of the study is redefined, so that the nature and quality of data collected can meet the needs of the goal of the study.

Figure 10 Phases in Conducting an LCA Study (Adapted from BSi, 1997: 4)



Working within this framework, the standards still provide enough flexibility in approach to allow practitioners to adapt the LCA to meet the needs of the decision context. Additionally, a guide has been published to aid practitioners in fulfilling the requirements set out in the ISO standards (Guinée *et al*, 2001). The guide covers all the stages in LCA and attempts to provide a comprehensive review of current best practice in procedures, guidelines and models; however, the extent to which it truly represents the full range of the ISO approach is a matter for debate.

The principal objectives addressed by the creation of standards are:

- To provide a degree of consistency in approach in conducting LCA studies;
- To guarantee a level of professionalism amongst practitioners;
- To prevent use of results from studies in ways which are not justified by the defined goal and scope;
- To provide an additional method of quality control in evaluating the results of LCA studies.

4.4.2 Differing Views on the Use and Purpose of LCA Methodology

Like the crises that have afflicted the fields of risk and operational research, a similar divergence in views on methodology development is ongoing in the LCA community. This difference of opinion between practitioners can be discerned between those who believe that LCA should develop as a purely objective and standardised analytical tool and those who feel that the methodology should be adaptable to the context in which it is used. Again it is the case that quite apart from the theoretical objections to the former position, the practical experience of using the methodology demonstrates that the application of an entirely standardised approach is an impossibility except in support of simple, routinised decisions. The argument put forward here is that more complex decision contexts require an entirely different approach to decision support. This is not an argument against the use of LCA as an analytical tool where its use is entirely appropriate, but rather that the methodology should be flexible enough to adapt to support decisions made in both simple and complex contexts.

There are further parallels with Rosenhead's critique of operational research methodologies which are relevant to a description of different approaches to applying LCA methodology to support decision processes. With reference to Table 4 in Section 4.3 above, a distinction can also be drawn between "tactical" and "strategic" applications of LCA, illustrated in Table 7 by restating Rosenhead's observations. While the current characteristics of "standardised" LCA methodology can be thought of as being allied with the description of an approach to "tactical applications", Section 4.4.3.2 and 4.4.4 describe progress made towards addressing the requirements of "strategic applications".

Table 7 Applying Rosenhead's Critique of Operational Research to the Characteristics of LCA Used in Different Decision Contexts

Characteristics of LCA Used in "Tactical Applications"	New Approaches to LCA Required for Use in "Strategic Applications"
Problem formulation in terms of a single objective and optimisation. Multiple objectives, if recognised, are subjected to trade-off on a common scale.	Non-optimising; seeks alternative solutions which are acceptable on separate dimensions, without trade-offs.
Overwhelming data demands, with consequent problems of distortion, data availability and data credibility.	Reduced data demands, achieved by greater integration of hard and soft data with social judgements.
Scientization and depoliticization, assumed consensus.	Simplicity and transparency, aimed at clarifying the terms of conflict.
People are treated as passive objects.	Conceptualises people as active subjects.
Assumption of a single decision maker with abstract objectives from which concrete actions can be deduced for implementation through a hierarchical chain of command.	Facilitates planning from the bottom-up.
Attempts to abolish future uncertainty, and pre-take future decisions.	Accepts uncertainty, and aims to keep options open for later resolution.

Rosenhead's terminology of "tactical" and "strategic" applications can also be thought of as similar in concept to Ravetz's descriptions of the conditions where the use of "normal" and "post-normal" science is appropriate (Section 3.1). Underlying both descriptions of the decision context is the degree of complexity embodied within the problem situation. Thus it is the perceived complexity of the decision context that will largely determine the validity or appropriateness of using a particular type of decision support methodology in policy decisions. Some important considerations in making such choices of methodology are likely to include:

- The potential that consideration of more than one perspective in analysing the problem situation will be necessary (and hence the questioning of whether it is appropriate to use a standard model in the situation);
- The magnitude of the "decision stakes" (Ravetz, 1997);
- The degree of difficulty in defining the decision context and objectives that decision options should address;
- The importance of value judgements and ethical considerations in the decision;
- The number and type of key players and stakeholders having an interest in the decision;
- The need to make decisions available for public scrutiny (or the degree of public accountability);
- The degree of uncertainty or risk associated with the decision context, including the formulation of the decision itself, the information or data describing the problem situation and the expected consequences associated with decision options.

It is helpful at this point to distinguish between using LCA to inform policy decisions in simple and complex decision contexts (as described in Section 3). To characterise the decision context, Cowell (1998: 202) suggests that a distinction can be made between the application of LCA to support operational and strategic decisions. Operational decisions are concerned with changes of small-scale systems with short time horizons, whereas strategic decisions concern large and qualitative changes of large-scale systems with longer time horizons. This is similar to the distinction made above between "tactical" and "strategic" applications.

If a simple decision context is envisaged, then a "tactical" approach may be wholly justified. An example would be the redesign of an existing product or a manufacturing process by a commercial organisation. Here, it is often clear that the goal and scope of the study may focus exclusively on narrow objectives such as decreasing energy intensity or material inputs to the product system. The systems in themselves may be complicated (see section 2) but only a single perspective will be needed to describe the problem, despite the difficulties encountered in constructing a model to describe the system.

However, this approach cannot be extended successfully to complex decision contexts such as public policy formulation, where a number of perspectives require consideration. Where this has been attempted, the studies have been largely unhelpful. A classic example was the McDonald Corporation attempting to defend its polystyrene foam packaging from justified criticism by citing a study by Franklin Associates, indicating that it had lower impacts associated with it than its paperboard alternative (Duda and Shaw, 1997; Franklin Associates, 1990). This was roundly criticised, since the original study had been produced for a specific set of circumstances and had been uncritically applied to a more general claim that one type of packaging was universally better in an environmental sense. Marketing claims to defend choices of one packaging material over another are just such decisions where it is not immediately apparent that the science is "post-normal" rather than "normal". Finnveden has also observed that the limitations of the methodology become apparent when there are "organisations involved which are strong enough to challenge the basis for decisions" (2000: 235). It is argued that these higher profile and more politically charged decision contexts require a different approach.

4.4.3 LCA as a Decision Support Tool

Bras-Klapwijk (1999) has pointed out the tension in the use of LCA methodology between adopting a "rational" and a "discourse" approach to policy processes. Her persuasive analysis of the two positions can be likened to the discussion of simple and complex decision contexts in Section 3 and 4.4.2. This is similar to Rosenhead's description of "tactical" and "strategic" applications of operational research, described at length in 4.4.2. There are certainly parallels which can be drawn between his critique of operational research and Bras-Klapwijk's analysis of perspectives used in conducting LCA studies. The main features of these two perspectives are summarised in Table 8.

Table 8 Main Features of the Rational and the Discourse Perspective for LCA Studies (Adapted from Bras-Klapwijk, 1999: 125)

	Rational Paradigm	Discourse Paradigm
Policymakers	Single Policymaker	Political Interaction
Inquiry Paradigm	Positivist or Neo-Positivist	Postmodern
Role of LCA or Other Analyses	Objective, Instrumental Guidance	Normative, Basis for Discussion

4.4.3.1 The "Rational" Approach (Bras-Klapwijk, 1999)

Bras-Klapwijk feels that the mainstream approach to carrying out LCA studies for use in policy making is grounded in a rational approach to decision making. The implicit assumptions are that:

- Policies are made ideally by a single decision maker with clear and consistent goals;
- Objective analysis of a problem situation is possible and/ or should be the desired outcome;
- Analyses should have a neutral, instrumental role in the policy making process (1999: 97).

She refers to the development of LCA methodology as a form of "means-ends" analysis (1999: 98). This essentially separates questions of values or ethics regarding the objectives of the study from the scientific analysis of alternatives to achieve them. Policy formulation is approached by identifying the ends the policy should achieve, followed by an analysis to determine the best means of achieving those ends. It follows from this position that, until recently, the role of LCA in decision making should be to provide "objective, conclusive, quantitative rankings" for policy alternatives (*ibid.*: 101). The policy-making activity and decision making is left to the policy maker alone.

The main observations defining the type of assumptions made by LCA practitioners who agree with the rational perspective can be summarised as follows. The assumptions are implicit in the current methodology and in aspirations to improve it in the future.

- **Objectivity in Method of Inquiry and Results Obtained (1999: 101)**
  Results obtained from the analysis should be based on formal, scientific enquiry. Subjective and qualitative valuations should be excluded from the analysis. The end point of the analysis should be a number of "unequivocal and authoritative" recommendations. These results should preferably be conclusive and quantitative.
- **All Environmental Policy Decisions Should be Based on the Same Environmental Criteria (1999: 102)**
  A number of LCA practitioners have asserted that all decisions in matters of environmental policy should ideally be supported by LCA that uses a defined set of environmental criteria for every study. Furthermore, the weightings applied to the criteria in the assessment should be common to all studies. The emphasis should be on consistency in approach to environmental product policies, so that studies can be compared on an equivalent basis.
- **Ideally LCA Methodology Should be Capable of Documenting and Quantifying a Complete Analysis of the Product System (1999: 102)**
  Developments in LCA methodology should include assessments of factors such as costs, employment conditions, utility value and safety. The objective is to provide a complete and quantified assessment of the interaction of the product system with the environment in a broad sense.

From this perspective, the basic quantitative methodology is sound but improvements may be made to increase the acceptability of the results among decision-makers. Some suggestions to improve the methodology have included:

- Adding sensitivity analysis;
- Improving the transparency of data issues, methodological assumptions and uncertainties;
- Changing the manner in which the study is conducted from a social perspective to increase the acceptance of decision outcomes, such as by introducing peer reviews or increasing the participation of stakeholders (1999: 111).

However, the results of an LCA are usually not unequivocal or impartial. While this may give rise to credibility problems in public policy debates, it need not do so if the extent of applicability of results is well defined and some possible shortcomings in the methodology are addressed. To date, much effort has been expended on developing standards for the methodology used to conduct LCA studies. This was seen as vital to the more widespread use of LCA, since many companies initially commissioned LCA studies to prove that their products were more "environmentally friendly" than those of their competitors. However, it was possible for experienced practitioners to evaluate the same product system and report different results, which is seen as unacceptable in terms of meeting the scientific standard for "repeatability" in assessment data. This has been the main source of the credibility problems alluded to above. A number of organisations have contributed to the development of current approaches, culminating in the publication of International Standards to provide a framework within which LCA studies should be conducted. This can be regarded as a response to the need to harmonise methodological procedures in order to address such concerns regarding the consistency of results from studies.

4.4.3.2 The "Discourse[13]" Approach (Bras-Klapwijk, 1999)

Bras-Klapwijk makes the observation that the "assumptions of the rational paradigm are not valid for public environmental product policies and product evaluations" (1999: 125). She proposes an alternative approach to conducting and LCA study where the "key function […] is to support the discourse of network actors" (1999: 113). She develops a "postmodern enquiry paradigm" (1999: 117) for LCA methodology, which questions some of the implicit assumptions of the "rational" approach.

[13] This approach is influenced by the philosophic theory of "discourse ethics", developed by Jürgen Habermas. An important concept here is the ideal of rational, informed discussion of public policy, to arrive at consensus for the validity of moral judgements. This validity is dependent on the degree to which such moral judgements are agreed with and accepted by freely acting agents. This describes optimal deliberation in ideal conditions, in which participants are able to reason and express their views without fear of constraint or control. However, in the context of approaches to public policy discourse, it is incorrect to describe Habermas as contributing to a "postmodern" approach. The source of morality for Habermas derives from "reason", which can be contrasted with the tendency of postmodern theorists to ground morality in human relationships. Furthermore, the objective, rational pursuit of justice tends to preoccupy modernist morality while the subjective, relational pursuit of care is of concern to the postmodernist writers (see Scott (2000) for further discussion). Other commentators have cast doubt on the applicability of discourse ethics more generally to problems of environmental ethics. For example, Smith (2001) has described the prospects of reconciling this schism between anthropocentric and ecological approaches as "remote" within the theoretical treatment offered by Habermas. Smith states that "the obvious problem for any environmental ethic is that since animals, waterfalls and so on presumably lack the capacity to engage in 'rational discourse' nature lacks any voice at all in this anthropocentric roundtable" (2001: 53). Even more importantly than this, Habermas does not countenance the idea that anything other than a rational agent capable of communication is capable of being a morally considerable subject. This is despite the ready assumption of ethical responsibilities for humans unable to participate in the rational speech (such as children), which indicates that the lack of ability to participate in human speech should not be a barrier to the consideration of nature's interests (*ibid*.).

The main points made relate to the way in which environmental decisions are made in the public arena. They can be listed as follows:

- Policies are made during political interaction processes, not by a single decision maker;
- Knowledge is not objective but is influenced by value judgements and social construction;
- The analyses should provide a basis for discussion of relevant factual information and values.

(1999: 124-131)

She is critical of mainstream approaches to LCA methodology and sees them as grounded in the rational approach. Based on her own work on PVC policies in the Netherlands, she observes that the following characteristics cause difficulties in the policy making process.

- LCA's apparent objectivity, simple results and the black box nature of the calculations make LCAs vulnerable to misuse;
- LCAs do not inform policy makers in a rich way due to the simplified and unclear conceptualisation [of the PVC issue], ignorance of key issues and absence of justifying arguments for choices containing normative issues;
- The LCA methodology contains implicit frames and values […].

(1999:153-154)

Bras-Klapwijk goes on to argue that LCA methodology can be improved by addressing the following areas. She sees this as essential to avoid the problems discussed (1999: 154).

- **Adding a Conceptual Modelling Stage**
  It is intended that this stage would precede inventory analysis and data collection. Here perceptions and framing issues would be considered and discussed. The objective would be to make the analysis less instrumental and to make sure that important issues are not omitted from the analysis.
- **Adding a Stage to Define Research Questions**
  Research questions and strategies should not be prescriptive in the methodology but should emerge from the decision process. Ideally, a preliminary discussion to establish the research questions should take place prior to research starting on an LCA.
- **Explicating and Studying Values and Frames**[14]
  Values and frames should be explored explicitly in the analysis. She sees a conflict here with the aspirations of some LCA scientists to remove normative issues from LCA studies, in pursuit of objectivity. She also disagrees with the use of standard goals and weighting factors in the analysis, since this may exclude the consideration of values and frames.
- **Increasing the Variety of Research Methods and Techniques in LCA Methodology**
  This proposal opposes the aspirations of LCA scientists who support greater standardisation of LCA methodology. She argues that a variety of methods of

[14] In this context, "frames" has been interpreted to describe the way in which decisions are made as to what type of information it is appropriate to include or exclude from the study. It is also concerned with all issues connected with setting the system boundary.

inquiry are required to address the divergent frames and values amongst policy makers, but also because a number of different types of research questions will emerge during the decision process.

- **Presenting Information in a Transparent Manner**
  Although explaining the ideas used in formal methods is viewed as a step forward, she sees the development of less formal methods as a means of addressing presentation problems. She sees this as analogous to the "pragmatic approach of product evaluators" in industrial contexts. The task is to make more use of qualitative and simplified approaches to LCA, where the results are not presented in the form of absolute figures but provide a rich picture of the life cycle of the product system.

4.4.4 Support for the "Discourse Perspective" in Adapting LCA to Inform Public Decision Making or in "Strategic Applications"

A number of LCA practitioners have also challenged the "rational" perspective of LCA methodology on a number of different fronts and lend support to Bras-Klapwijk's assertion that a different approach is required in public policy uses. Wrisberg *et al.* (2002) take up the distinction between applications of LCA methodology in simple and complex decision contexts, and identify public involvement and public disclosure of results as requiring special consideration. As it is observed,

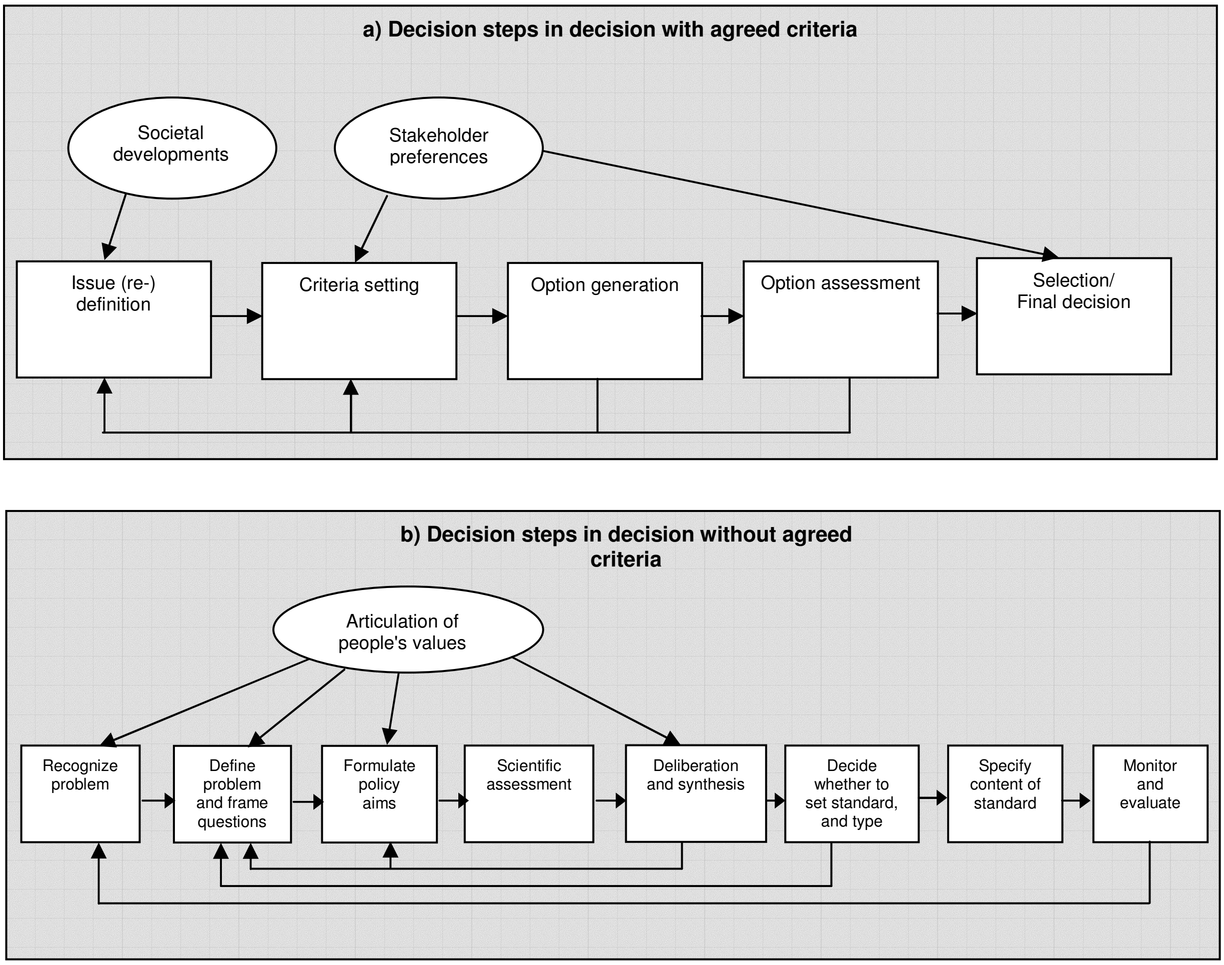
> [H]ere a range can be defined between regular, routine decisions to single unique decisions. The first will generally be internal, with low public involvement; the latter will generally be external with a possible large involvement of the public. A specific category of decisions in this range concerns the 'comparative assertions disclosed to the public' as specified in the ISO 14040 series on LCA.
>
> (Wrisberg *et al*, 2002: 23)

Udo de Haes *et al.* recognise that these situations will require different types of decision support. The differences are summarised with reference to a Royal Commission on Environmental Pollution (RCEP, 1998) report concerning the "Setting of Environmental Standards", in terms of a distinction made by Cohon (1978) between decisions where agreement has been reached on criteria and those without such agreement. Figure 11 summarises the differences suggested in the type of process required for each type of decision context. It is noted that "(S)ituations without agreed criteria need a more elaborate process, with more emphasis on the articulation of the people's values" (Wrisberg *et al*, 2002: 23).

Cowell *et al* (1997) have considered a number of case studies and explored how LCA could provide better information for decision making. They suggest that stakeholders should ideally be involved at all stages of conducting an LCA, where a stakeholder is defined as "someone with a legitimate interest in the decision" (1997: 12), the implication being that "legitimacy" is to be defined by some reflexive process among potential stakeholders so that forming the group of stakeholders is a decision process in itself. This was identified as a research area deserving attention in the future, lending further support to the need to acknowledge the existence of group decision making and social processes as part of the LCA methodology.

Hofstetter *et al* (2000) identified uncertainty in values and system behaviour as two key areas to be addressed to allow LCA's development as a decision support tool (p 161). Drawing on research in the field of risk perception (and especially cultural theory as described in Section 3.2), it is argued that decision makers' values should be incorporated into LCA methodology (p162). This was an open acknowledgement of the need to consider decisions made by groups in designing LCA as a supporting tool and to accommodate a diversity of stakeholder views. Hofstetter *et al.* also argue that the impact assessment phase requires broadening to incorporate an indicator for unknown damage and another for the manageability of expected damages (p162).

Figure 11 Decision Steps a.) for Decisions with Agreed Criteria and b.) for Decisions without Agreed Criteria (RCEP, 1998)



Finnveden (1997) recognised that the valuation phase required "political, ideological and/or ethical values" to determine how "different environmental features are valued against each other" (p 163). He asserts that, because of the implicit valuations at all stages of the analysis, a "prerequisite for an increased agreement on valuation methods may be that ethical and ideological values of relevance are discussed more explicitly" (p168). These concerns parallel those of Ravetz in describing situations where science becomes "post-normal"; i.e. where "the loss of certainty and the intrusion of ethics" destroy the basis for a "normal" scientific approach (Ravetz, 1997: 534).

In a later paper, Finnveden extended and broadened his critique of LCA methodology, identifying some of the difficulties experienced in practice, in using the outputs in policy making processes (Finnveden, 2000). His main criticism is that

> [I]t is concluded that it can in general not be shown that one product is environmentally preferable to another one, even if this happens to be the case […] If policy changes require that it must be shown that one product is more (or less) preferable before any action can take place, then it is likely that no action is ever going to take place. If we want changes to be made, decisions must be taken on a less rigid basis.
>
> (2000: 229)

The reasons given for his position relate to methodological observations and theoretical arguments. The methodological observations fall into three main categories, which he argues are generic and applicable to all environmental systems analysis tools:

1. Not all the relevant environmental impacts are considered;
2. There are uncertainties:
a) In data,
b) In methodology for the inventory analysis and the impact assessment, and
c) In the description of the studied system;
3. The weighting element involves ideological and ethical values which cannot be objectively determined.

(2000: 230)

A possible consequence of the difficulties in product comparisons is that LCAs may be used in policy-making debates as a "defensive" tool. In this case the company or authority may claim that until it is proven that alternatives are better, no action should be taken (2000: 235). As Finnveden argues that this cannot be proven conclusively using LCA methodology alone, then demanding such objective scientific proof becomes an effective strategy for procrastination.

Finnveden's analysis can be seen as an acknowledgement of the need for a "post-normal" science approach and also as a critique of LCA's applicability to "strategic" problems, with the obvious parallels to the evolution of structuring methods for strategic decision support, as described in Section 4.3. A clear challenge for LCA methodology in the future will be to address the need to support such policy decisions effectively, finding new means to accommodate group decision-making and uncertainties encountered in the decision process.

4.4.5 Summary

This synopsis of the application of LCA methodology to support different types of decisions is reflected in current debate among LCA practitioners. At the heart of this discussion is the question of whether LCA methodology should be adaptive to the context in which decisions are made. There is an inherent tension between the need to be adaptive and the wish to provide a complete analysis of environmental effects. Rosenhead's critique of operational research and description of subsequent developments in related disciplines to provide structuring methods for strategic decision support are instructive, bringing new insights into some possible ways of accommodating complexity in decision contexts with LCA methodology.

LCA is a valuable input to any policy decision process concerning product systems, because of its unique focus on the whole life cycle. As Finnveden observes, it is for this reason that it “can not be completely replaced by any other tool” (2000: 236). However, it has also been demonstrated that it does not provide a complete picture of the environmental consequences of a particular product system in comparison with another; the information provided by the analysis alone is not sufficient to allow such statements to be made. The use of a single rational analytical tool will also violate Arrow’s impossibility theorem, in that group preferences cannot be aggregated into a single preference by the use of an analytical method alone. It follows that it is incorrect to describe LCA as a decision making tool. Using this methodology, it is not possible to accumulate the requisite information to allow a decision to be made. This issue is considered further in Section 5 below.

However, LCA can be characterised as a methodology where the challenges of increasing the relevance of the study outputs to the decision context are receiving attention. This is especially the case for public policy decisions. The evolution of participatory approaches to LCA embodied by the “discourse” approach, an appreciation of uncertainties in the assessment and a thorough consideration of normative criteria are receiving attention. This mirrors developments in risk management and operational research methodologies in their adaptation to use in complex decision contexts. This is to be welcomed as a positive step towards a greater acceptance of the legitimacy of the methodology as an input to environmental policy decisions.

It is possible that a number of existing tools could be used with LCA studies, to provide more flexible decision support, and clear that such combinations of tools should be used to a much wider extent in the future. For example, to study values and frames in decisions, an obvious contender is SODA, with its cognitive mapping methodology. A key research need will be to evaluate what such tools can contribute to decision-making processes and whether using a range of methods compensates for any individual potential weaknesses arising from the use of each method in isolation.

5 Using LCA with Other Decision Support Tools in Public Policy Making

This review concludes by examining the various criticisms of standardised LCA methodologies in public policy contexts. The criteria provided by Rosenhead and Ravetz concerning methodologies that are likely to be useful in such complex decision contexts is used to appraise new approaches where a number of decision support methodologies have been used in combination with LCA. Bras-Klapwijk's approach to defining a "discourse" perspective of LCA methodology is also relevant to this critique. The criteria outlined are also used to determine the types of combined methodology that would benefit from further research in the future. While this is a rapidly expanding field, the commentary is limited to the following combinations with LCA:

- Economic Approaches;
- Environmental Impact Assessment;
- Cultural Theory;
- Structuring methods for strategic decision support.

5.1 Economic Approaches

Economic approaches to policy decision support in LCA have focussed on the valuation phase. This is arguably one of the most contentious phases in LCA, since it determines the interpretation of the data and the weighting applied to transform life cycle inventory data into environmental impacts. In public policy debates, this is certainly a point at which one would wish to consider society's values as they apply to the particular decision context. Powell *et al* (1997) compared four approaches to valuation: distance to target methods, environmental control costs, environmental damage costs and scoring approaches. In their view, the first three approaches may be instances of "implied social weighting: that is weights are 'revealed' via the political process of setting environmental standards or via explicit or implicit market valuations" (1997: 11). The fourth method is seen as different in that a smaller subset of people rather than "society" can be seen as involved in the weighting process.

Their critique of distance to target methods has been shared by other LCA practitioners: they are based on unjustifiable assumptions that "all targets are equally important" so that they are perhaps not weightings at all, in the normal sense of the word, but simply extended normalisation methods. An example of a valuation methodology using this method is Swiss Ecopoints (1997: 12). Likewise, there has been criticism of scoring valuation methods on the basis that they reflect experts' weightings and not those of society as a whole.

However, their proposed solutions are also deeply flawed and do not address the problem of evaluating society's valuation of environmental interventions in LCA methodology. Powell *et al* see the use of environmental damage costs, elicited from individuals in the form of *willingness to pay* (WTP) values to avoid damage caused by environmental interventions, as a way forward. The difficulties inherent in using contingent valuation to evaluate WTP were discussed in Section 4.1, in the context of cost-benefit analysis. An alternative is to use expenditure costs necessary to prevent environmental damage, for which the "underlying rationale" is that "society has expressed its 'willingness to pay' for achieving the standard [of environmental protection] by implicitly voting the expenditure required to achieve the standard" (1997:12).

Quite apart from the theoretical difficulties encountered in aggregating individual preferences to arrive at one value that allegedly represents society's values (thus violating Arrow's impossibility theorum), these methods add another level of opacity to the analysis. The original criticisms of LCA valuation methodology relate to the difficulty in assessing results because of a lack of transparency and a failure to account for the values of society rather than experts' values in the assessment. Rather than using direct evaluations of expected environmental damage, it is expected by Powell *et al* that abstracting this information into monetary evaluations will be helpful, even though the magnitude of the figures will now be unconnected with a description of the environmental damage that is the subject of the decision. As discussed in Section 4.4, using LCA in complex decision contexts requires greater transparency and a willingness to be explicit in discussing perspectives used in valuation. It is difficult to imagine how the economic approaches to valuation described could ever be useful in public policy contexts, since they would serve to further obfuscate the decision process.

Another crucial consideration absent from the analysis of Powell *et al* is the consideration that such public policy decisions are made by a number of key players and stakeholders, not by a single decision-maker aided by a single analytical tool. The failure to engage with this important consideration means that it is unlikely that the combination of a standard LCA with an economic valuation stage could be useful in public policy contexts, where a complex network of interest groups would need to be considered in the decision process.

5.2 Environmental Impact Assessment

Tukker (2000) sees a role for LCA in conducting Environmental Impact Assessment (EIA). Since environmental comparisons of alternatives for processes and pollution control technologies are often a feature of EIA at a strategic level, he argues that LCA can contribute to environmental evaluation in EIA by allowing a "system approach that takes into account all environmental effects" (2000: 435). By this, he is referring to the need in EIA to consider all "indirect effects" in the analysis (2000: 454). His analysis that there is no fundamental difference between the two approaches is interesting, since many authors have argued that the two types of assessment are methodologically distinct. Tukker has illustrated a commonality in approach, in that there are common steps at which evaluation criteria are defined, system boundaries are defined, an inventory of environmental interventions is defined and alternatives are appraised for optimal reduction of environmental impacts (2000: 437). EIA is often represented as " a local, point source oriented evaluation of environmental impacts" while LCA is seen as more general, "with its emphasis on time and location-independent assessment of potential impacts in relation to an entire production system" (2000: 435-436). Another way of expressing this would be to assert that while EIA tends to be specific to a set of local circumstances that are time dependent, LCA is depicted as universal and time independent. He also notes that the differences perceived between the methodologies have been recognised at least in part because of the different legislation governing their use and the ensuing existence of two separate communities of practitioners.

Tukker's assertion that a systems approach would be helpful in carrying out EIA is a salient point. EIA used at a strategic level would need to take account of wider interactions than, for example, alternatives for production at a single production site. The effects of each alternative on the environmental impacts arising from the product system as a whole would also require evaluation (2000: 443-446). LCA would certainly assist with taking this more strategic view of the product system. However, his assertion that the LCA is capable of taking into account all the environmental effects is erroneous. Tukker fails to address the question of whether an EIA approach, being specific to local circumstances, might also be a useful perspective in conducting LCAs. Localised environmental concerns are usually absent from policy oriented LCA studies, often to the detriment of the analysis. There may be a role for an EIA approach in policy applications, where the more local focus would add some much needed detail to the broader and more global emphasis embodied by approaches to LCA. After all, in applications such as siting municipal waste incinerators, questions from local stakeholder representatives are likely to be concerned with local rather than global effects. It is important that such effects are given consideration in the decision process and a more widespread willingness to combine the strengths of EIA with LCA may assist with this.

This use of the two approaches does not however solve the question of how to arrive at weightings to apply to criteria in evaluating the relative importance of local and global environmental effects. In other words, valuation is still an unresolved problem. The decisions to include or exclude criteria from the analysis are similarly not given consideration. Neither does it address the relative importance of other salient objectives related to financial, technical and social criteria in the policy decision process. It is also unclear how this combination of approaches could be used to support group decisions explicitly, though the acknowledgement that there may be a role for other tools in addition to LCA is welcome.

5.3 Cultural Theory

Hofstetter *et al* have recognised the need to address uncertainties in decision makers' values and in system behaviour in LCA methodology (2000: 161). It is suggested that a means of incorporating values would be to model the "valuesphere" within the LCA methodology, with reference to the four archetypes of human worldview presented in cultural theory (see Section 3.2 for further explanation): individualist, egalitarian, hierarchist and fatalist. Each has been related to a particular view of nature and attitudes towards environmental management. Hofstetter *et al* argue that, since it can be shown that the first three perspectives dominate among stakeholder and interest groups, three sub-models can be used to address attitudes to risk and uncertainty in LCA studies. It is claimed that the three sub-models listed could provide the knowledge required to fully model interactions of the technosphere with the ecosphere as follows (2000: 165):

- Damage assessment based on known causalities;
- Unknown damages or unknown causalities;
- Manageability.

Earlier sections pointed out the widespread agreement that it is necessary to make the values involved in policy applications of LCA explicit. The view of Hofstetter *et al* regarding the resolution of group decision making conflicts, that “it is obvious in such a situation that it is not the further discussion of technical points that will bring a solution but that there is a value debate” stage required, is therefore apposite (2000: 167). However, it is not clear that LCA including these frames of reference will be successful in providing the “basis for applying discursive methods of conflict resolution” (*ibid.*), nor that the use of these three perspectives will adequately describe the social interaction of key players and stakeholders in the decision process, especially since empirical evidence for this classification of worldviews is sparse at present.

Hofstetter *et al* do not address the means to effect conflict resolution, although this is the aspect most urgently required to support public policy decision processes. The key difficulties with LCA in strategic applications are the lack of transparency of results and the lack of consideration of implicit values. While the approach based on cultural theory will at least provide an overview of some different ways of evaluating uncertainty in the modelling process, it is unclear how this assists with making these assumptions transparent. The implicit values may be related to the three archetypes described, but it is unclear how these assumptions could be articulated explicitly in the decision process. It is also not clear that these values will reflect the actual values possessed by key players and stakeholders involved in the group decision process. If the model does not provide an accurate reflection of the group’s values, it is difficult to see how the method can be useful in practice. The process of eliciting the group’s actual values is likely to be more instructive and would naturally lead to an exploration of possible conflicts.

In public policy decisions, the range of issues required is wider than those covered by an LCA study, to include social and economic as well as environmental criteria. The application of cultural theory does not address this need. It is unlikely that the scope of a public policy decision could be addressed by the use of LCA in combination with an approach based in cultural theory. At best, the application of cultural theory could provide an additional means of sensitivity analysis during the LCA modelling process.

5.4 Structuring Methods for Strategic Decision Support

As mentioned in Section 4.3.5, the four methods discussed in detail in Section 4.3 can be broadly classified by their expected function within policy decision processes. Although AHP has received the most coverage to date in environmental applications, since it is a relatively "hard" approach, it is expected that some difficulties would be encountered in using it in strategic decision contexts. The “softer” approaches of SODA and SSM have an obvious role in addressing nebulous decision contexts,where there is no agreement among the group involved in decision making concerning the definition of the decision to be made, much less to the options to be considered as alternative solutions. These methods can be used to address the requirements for a “discourse” approach to LCA methodology that Bras-Klapwijk identified. This involves the addition of a conceptual modelling stage, adding a stage to define research questions and a stage to explicitly study values and frames in the decision process.

Decision conferences using MCDA methodology can also be adapted to this type of enquiry process, by approaching the question with a group of key players and stakeholders to explore strategic issues. The comparison between this methodology and LCA is summarised in Table 9, drawn up to describe their applicability to a specific decision (appraising sustainability of highway maintenance services; Elghali, 2002) but nevertheless providing a general comparison for policy decisions. The methods are generally compatible with one another, leading to an expectation that the shortcomings of either method would be compensated by the use of the other. For example, MCDA gives consideration to a broad range of decision criteria which are elicited directly in connection with the decision under consideration. LCA raises issues that key players and stakeholders might not have considered if the MCDA was carried out in isolation and provides detailed data concerning environmental impacts that would not otherwise be available. LCA can also provide another perspective to the discussion: a discussion of future potential environmental impacts, which is important to any discussion of sustainable development. Provided that LCA is used in a "discourse" application, both methods are potentially educational for participants.

In other circumstances, the decision context will be more defined and options for appraisal are more clearly delineated. However, in public policy contexts, a broad range of social, environmental and economic criteria will require consideration in attempting to optimise choices of options. In these cases, applying the technique of MCDA through the process of decision conferencing is likely to be useful, since the methodology can deal with a variety of different types of information and will assist in the process of structuring the decision at hand. The "harder" approach of AHP could possibly be helpful here, but it is greatly disadvantaged by its lack of theoretical grounding, its inability to provide a ready means of resolving conflicts amongst stakeholders and its inability to generate completely new decision options once the analysis has begun. For this reason it is likely to be more appropriate to use AHP in tactical rather than strategic applications.

Table 9 A Comparison of LCA and MCDA through the Process of Decision Conferencing

	LCA	***Using MCDA through the process of decision conferencing)***
Types of decision supported	Usually tactical, although applied to strategic decisions with varying degrees of success.	Tactical or strategic, but most useful for complex decision contexts.
Data Requirements	High. A broad range of data are required to conduct the assessment.	Variable and dependent on the decision context.
Data Quality Requirements	High. The assessment is adversely affected by imprecise data.	Variable and dependent on the decision context.
Type of Data	Quantitative	Qualitative as well as quantitative.
Decision Maker	Assumed single decision maker	Group decision making
Values	Not explicitly addressed but incorporated in abundance.	Explicitly addressed and made transparent.
Transparency of methodology	Relatively difficult for lay person to understand.	Easy for lay person to understand.
Potential to resolve conflicts between stakeholders	Depends on the way the methodology is used.	High and part of the process for decision conferencing.
Coverage of decision criteria with respect to sustainable development	Partial coverage of environmental issues only.	Potential to cover all relevant criteria for the decision at hand.
Provision of an audit trail for decisions	No	Yes
Provision of a systems approach	Yes	A systems approach can be used as an input if the decision context requires it, but this is not a prescribed part of the methodology.
Accommodation of uncertainty and risk	Sometimes if sensitivity analysis is carried out. However, not normally explicit, especially for data quality and valuation.	Easily accommodated and expressed as part of the analysis. Numerous sensitivity analyses can capture the group's thoughts on this.
Are trade-offs on decision criteria explicit?	No	Yes
Is double counting a problem?	Yes	No

Multi-criteria analysis methods have been proposed to address some of the problems encountered in the valuation phase of LCA studies. Seppälä (1998) has created a decision analysis impact assessment (DAIA) using the general framework proposed by multi-attribute value theory described in Section 4.3.3. The objective of the study was to rank main life cycle stages and stressors in an LCA conducted for the Finnish forest sector. Impact category weights were obtained from 58 experts working with environmental issues, using questionnaires. However, the study did not draw on the wider lessons from operational research methodology and related disciplines (see Section 4.3), the need for a "discourse" approach to LCA, or recognise that a thorough accommodation of the social context of the decision is required for complex decision contexts such as policy or strategy applications. Seppälä *et al* (2002) have also discussed the possible use of Multiple-Attribute Decision Analysis (MADA)[15] in Life Cycle Impact Assessment (LCIA). However, their approach set out to provide "a clear axiomatic foundation for rational decision making under multiple objectives", and is therefore subject to the same criticism. The weightings obtained from experts will still reflect experts' value judgements which are not explicit in the assessment. This is implied by references to "handling subjective inputs". Seppälä's emphasis on experts as the source of all relevant knowledge is also disappointing (2001: 121-128), given that the field of risk management has long established this position as untenable. It is also difficult to see how this provides a solution to problems of lack of transparency and the need to make decision-makers publicly accountable for their deliberations.

Seppälä is happy that the use of "individual interviews" was applied without a "face to face situation" (use of questionnaires). He assumes that this is advantageous in comparison with "potential bias from group dynamics" that is experienced otherwise (2001: 126). However, it is precisely such group dynamics that are captured in the use of MCDA through the process of decision conferencing and provide the social interaction basis for conflict resolution[16] among decision-makers and stakeholders. These two views broadly parallel the distinction between quantitative and qualitative research methods in social science. Seppälä's repeated assertion that the weightings used in LCA must be elicited from experts is also problematic and is contradicted by his statement that "[T]he real questions are how to ensure that weighting decisions are taken by those who are authorised to do so, and how scientific information can be absorbed by the respondents" (2001: 129). In plural societies, it is decision-makers and key stakeholders who are legitimately permitted to make decisions concerning the importance of decision criteria, not experts using analytical tools, no matter how well meaning they are. The question of absorbing scientific information implies that

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[15] The term multiple-attribute decision analysis is often used synonymously with multi-criteria decision analysis, with its origins in the normative decision theory developed by von Neumann and Morgenstern (1944) describing the calculation of subjective expected utility values (see Section 4.3.3). However, Seppälä *et al* (2002) have defined MADA in the sense that other authors often use the term multi-criteria analysis (MCA). For example, MCA is defined as "any structured approach to determine overall preferences among alternative options, where the options accomplish several objectives" in the UK Government's manual (DETR, 2000: 146). This illustrates the importance of defining terminology carefully, as they are often used to describe different methods or groups of methods. Thus, in this working paper, MCDA/ MADA has been regarded as a highly developed subset of MCA approaches. The term MCA is also often regarded as having a terminology problem, in that its definition is often imprecise, and may also include optimising techniques (e.g. the use of iterative algorithms). In this working paper, MCA is not considered to include such optimising techniques, although it is clear that Seppälä *et al* (2002) have included them in their definition of MADA.

[16] This is not to imply that it is always possible to reach a group consensus view on scoring and weighting. The reflexive modelling process simply assists in clarifying areas of conflict, while at the same time allowing the group to create a shared understanding of the decision context. However, because of the tendency of MCDA models to be rather insensitive to changes in individual scores and weights, the most protracted arguments between stakeholders over such issues often have little relevance to the final selection of options. This allows the group to focus discussion on the criteria having a direct bearing on the choice between options. It is this provision of a framework for the group to think clearly about the decision at hand which is the most useful feature of the methodology. See Section 4.3.3 for further details.

there may well be a learning process involved, but also a simplification process to allow greater transparency and understanding of issues.

It is interesting that Seppälä has picked out a specific difficulty in using decision analysis techniques for valuation in LCA: the difficulties with "double counting". This cannot be tolerated in most simple MCDA models because the criteria must be mutually preference independent. There are numerous areas in LCA impact categories where double counting of effects occurs. In Seppälä's example, oxygen depletion from organic discharges and eutrophication form separate categories, yet oxygen depletion can also arise as a secondary effect of eutrophication. This has the effect of rendering the weighting for oxygen depletion as a whole in the analysis greater than it has any right to be. One must question the validity of the results obtained in this study if, as is stated, "it is not easy to confirm the validity of this assumption [that the decision criteria are mutually preference independent]". This is a fundamental requirement to allow the use of the methodology, unless the non-independence is otherwise accounted for by using more complex modelling techniques or decision criteria are separated so that they can be considered independent (see section 4.3.3). Using MCDA with LCA in any form is thus likely to lead to a complete reworking of established impact categories to prevent such double counting. In terms of a decision analysis framework, this would be a distinct improvement on the current use of prescribed impact categories.

The application of MCDA through the process of decision conferencing has an advantage that is relevant to another goal of the "discourse" approach described by Bras-Klapwijk: to provide a means of simplifying LCA methodology in the interests of promoting transparency in the assessment. In Section 4.3.3, one of the main objectives in conducting MCDA is to arrive at the creation of a "requisite model" containing just enough information to resolve the problem situation that is the subject of the analysis. In practice, many of the stages of LCA would need to adapt and possibly be simplified in order to provide such a model. The emphasis is on collecting data and constructing models only in so far as they are helpful in making the decision. For example, it is unlikely to be acceptable to representatives of local people to use toxicity potentials as a surrogate for the exposure of a particular target to a particular toxin in a specific area. It is easy to imagine just such a scenario in evaluating the risks posed to humans by dioxins emitted from a municipal waste incinerator in deciding on a particular choice of siting or technology.

Environmental decisions for public policy contexts are primarily concerned with group decision-making activity. In a recent paper, Geurts and Joldersma have described "consensus conferences" (decision conferences) as helpful in addressing "the need for social interaction" between members of the group for complex policy problems (2001: 300). Cowell *et al* (1997) suggest the need for a framework to involve stakeholders, providing support for the simplification of LCA, since data demands could potentially be reduced by using participatory methods. In their view, this is possible because a discursive methodology could identify "hotspots" in the product system, in terms of either environmental impact or socio-political importance and focus on them, creating a requisite model. This is almost indistinguishable in approach to the use of MCDA through the process of decision conferencing, which elicits the important decision criteria from participants, with the expectation that either quantitative or qualitative data will then form the basis of assessment. The important distinction between current LCA methodology and this approach is that it is the participants who decide which criteria are important and should be included, and contribute to discussion about how particular data sources will best reflect their shared definitions of criteria. If there is concern that this will overlook important criteria from LCA studies because participants are unskilled in this area (or indeed other important decision objective areas for which specialised tools are used), then there may be a need to include participant training in the decision process.

This feature is useful, since one of the consistent criticisms of LCA studies is the time taken to conduct them and the costs involved. Both could be reduced dramatically by deciding in advance what information is necessary to address decision objectives. This is not an argument against conducting full LCA studies for product systems. Such studies often explode myths concerning the environmental impacts associated with products and services and this useful function should be retained. However, the "paralysis by analysis" argument is no less valid, leading to no action in the short term and the use of LCA as a delaying tactic by affected parties in policy debates, as Finnveden (2000: 235) has observed (see Section 4.4.4).

What emerges is the need for a different, non-generic and adaptive approach to using LCA in public policy decision contexts. This approach emphasises that LCA is only one among a number of possible tools to be used during the process of decision support, although LCA provides a useful perspective because of its systems approach and concern with the whole life cycle of a product system. As Finnveden (2000) has pointed out, this perspective is useful and cannot be replaced in its entirety by any other policy support tool. However, LCA methodology as it exists currently does not provide any real, structured support for decision-making activities and requires additional methodological development if the objective is to provide such support, especially for complex decision contexts.

The strength of using structuring methods for strategic decision support is that a broader scope of issues is considered, relevant to the decision context. Such methods provide a framework for decision support, which are able to use the information generated by LCAs as an input. However, making sure that the information from LCAs can be used in this way will also require methodological changes, such as those discussed in relation to positioning LCA data within a decision analysis framework.

There is also no *a priori* reason to suppose that the issues addressed in LCA will be the most relevant ones in the decision at hand. Therefore using a prescribed approach such as standardised LCA amounts to dictating what is legitimate and worthy of study. In the case of siting an incinerator, one could imagine certain stakeholders being more concerned with direct cancer risks and others with an increase in local traffic. Bras-Klapwijk has acknowledged this in her work on policies for PVC in the Netherlands, where she observed that "LCAs ignored important key issues in the PVC debate" (1997: 138). The challenge for LCA methodology is to make sure that other policy support tools can also be used to inform such policy decisions, so that the key issues are no longer ignored.

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