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An integrated sustainability decision-support framework Part I: Problem structuring

Adisa Azapagic and Slobodan Perdan*

*Centre for Environmental Strategy, School of Engineering, University of Surrey, Guildford, UK

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SUMMARY

One of the main goals in decision-making for sustainable development is to identify and choose the most sustainable option from among different alternatives. This process usually involves a large number of stakeholders with multiple, often conflicting, objectives. Facilitating and resolving such difficult decision situations can be complex, so that a more formal and systematic approach to decision-making may be necessary. This two-part paper proposes an integrated multiple criteria decision-support framework specifically developed to provide systematic, step-by-step guidance to decision-makers. The framework, which is suitable for both corporate and public policy-making in the context of sustainable development, comprises three steps: problem structuring, problem analysis and problem resolution. In this paper, the focus is on problem structuring while Part II concentrates on problem analysis and resolution. Problem structuring includes identification of stakeholders, sustainability issues and indicators relevant for a particular decision problem. Sustainability indicators are used as decision criteria for identifying and choosing the most sustainable option. In the problem analysis step, decision makers articulate their preferences for different decision criteria. A suitable Multiple Criteria Decision Analysis (MCDA) technique, such as multi-objective optimisation, goal programming, value-based and outranking approaches, is then used to model the preferences. These techniques are discussed in Part II, which also gives guidance on the choice of the most appropriate MCDA method. Based on the outcome of preference modelling, which estimates the overall 'value' of each alternative being considered, decision-makers can then choose the 'best' or most sustainable option. Such an integrated decision-support framework is useful for providing structure to the debate, ensuring dialogue among decision-makers and showing trade-offs between conflicting objectives. In this way, it may be possible to create shared understanding about the issues, generate a sense of common purpose, and often, resolve 'difficult' decision problems.

Correspondence: *Correspondence: Adisa Azapagic, Centre for Environmental Strategy, School of Engineering, University of Surrey, Guildford, Surrey GU2 7XH, UK. Email: a.azapagic@surrey.ac.uk

INTRODUCTION

One of the main challenges of sustainable development is to identify and adopt more sustainable options and activities from a set of alternatives by balancing economic, environmental and social aspects of each alternative. This is not a trivial task as it normally entails quite complex decision-making, which can be accompanied by a number of difficulties. First, decision-making in the context of sustainable development involves a number of different stakeholders who often have conflicting interests. Second, at one end of the spectrum, decision-makers may have to consider and compare a number of possible alternatives, often using a large number and type of decision criteria. At the other end, it may be unclear what the alternatives are or it may be difficult to find any suitable alternatives. It may also be unclear which decision criteria are relevant for a particular decision-making problem. For most decision-makers, an additional difficulty is related to the need to consider both quantitative and qualitative criteria, often based on imprecise or fuzzy information. Further complexities are introduced by the need for transparency and communication of the decision-making process to all interested parties. These difficulties are encountered to various degrees in both corporate and policy decision-making for sustainable development. To facilitate the decision-making processes, it is often necessary to take a more formal and structured approach to problem solving. The approaches used in Multiple Criteria Decision Analysis (MCDA) can provide significant assistance in sustainability decision-making.

One of the main aims of MCDA is to help decision-makers organise and synthesise information in a way that enables them to understand the problem, identify decision-making criteria and choose the 'best' solution based on the 'importance' they place on these criteria. Therefore, MCDA should be viewed as a tool which can help decision-makers to make 'good' decisions rather than prescribing how decisions should be made. The major advantages of MCDA over informal judgment are that the decision-making process is transparent, explicit, provides an audit trail and is open to scrutiny by all interested parties. Furthermore, it can provide an important means of communication between decision-makers but also between them and the wider community, if necessary. Another key advantage of MCDA is that it enables effective management of subjectivity rooted in decision-makers' value system. Values influence each stage of the decision-making process, from trying to understand the problem to choosing the 'right' solution. Failure to acknowledge subjectivity and to respect different value positions is usually a cause of conflict between different stakeholders. This is particularly important in the decision-making contexts related to sustainable development, where multiple decision-makers often hold opposing views on a particular issue or problem. Using a structured MCDA approach in these situations can help different stakeholders to understand their different value positions and to reach a compromise solution.

This two-part paper presents an integrated decision-support framework specifically tailored for decision-making in the context of sustainable development. The framework, which is underpinned by MCDA, is designed to provide systematic guidance to both corporate and policy decision-makers through a three step-process: problem structuring, problem analysis and problem resolution. This first part focuses on problem structuring, while the second (Azapagic and Perdan 2005) discusses problem analysis and resolution. A particular feature of the framework is a systems approach to decision-making.

SYSTEMS APPROACH TO DECISION-MAKING

Addressing the challenges of sustainable development requires a systems approach, where emphasis is placed on studying and understanding relationships between parts of the system and the functioning of the whole system in an integrated way (Azapagic and Perdan 2000; Azapagic 2003). This means that decision-makers must take a holistic view in trying to integrate and balance the three pillars of sustainable development: society, economy and the environment. The systems approach also means that decision alternatives must be evaluated on a life cycle basis, from 'cradle to grave', for different sustainability decision criteria (Azapagic and Perdan 2000). For example, to identify a more sustainable product among the alternatives, all activities, from the extraction of raw materials through the production and use of the product to post-use waste management, must be taken into account. The best option is then identified by evaluating alternative products on a number of identified economic, environmental and social criteria through the whole life cycle. In this way, decision-makers can make an informed decision based on a more complete understanding of the consequences of the chosen alternative on the environment, economy and society. On the other hand, decisions based on incomplete information obtained by concentrating on only a part of the system, perhaps on the production process or the use stage, can lead to a choice which is sustainable for that particular life cycle stage but unsustainable for the rest of the life cycle.

Although the systems approach to decision-making is congruent with the underlying principles of sustainable development and can help identify truly sustainable options, it can also further complicate the decision-making process. As discussed in the Introduction, the difficulties arise not only because of the complex systems that have to be analysed for a, usually, large number of sustainability criteria, but also because of a large number of stakeholders that may be affected by a particular decision. Therefore, these complex decision situations are best facilitated through a structured and systematically guided process. The decision-support framework described below shows how this could be achieved.

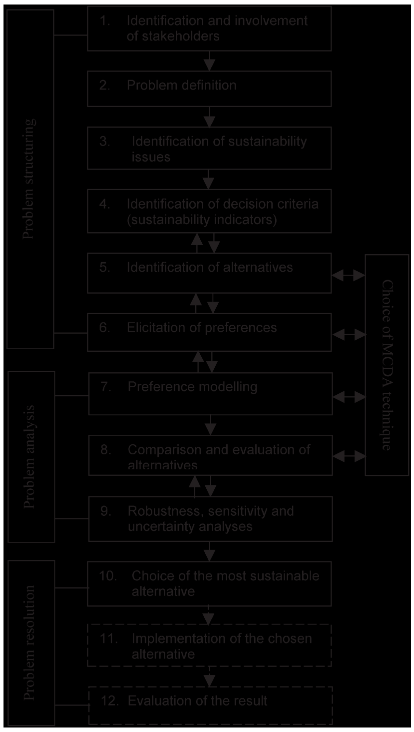

Figure 1 Integrated decision-support framework

AN INTEGRATED SUSTAINABILITY DECISION-SUPPORT FRAMEWORK

Regardless of the context, the decision-making process usually involves three general stages (Belton and Stewart 2002):

1. Problem structuring;
2. Problem analysis; and
3. Problem resolution.

These stages are revisited iteratively throughout the process, as appropriate, until a final decision is reached. As illustrated in Figure 1, the decision-support framework proposed here is also based on this general approach to decision-making. However, the specific steps within these three general stages have been developed specifically to make this framework suitable for decision-making in the context of sustainable development. In this proposed framework, the first, Problem Structuring stage, involves six steps. It starts with identification of decision-makers – in this context, the stakeholders. This is followed by a definition of the decision problem and the goal of decision analysis. The next step within this first stage is identification of key sustainability issues and the related sustainability indicators that decision-makers will use as decision criteria in assessing the alternatives, which are then identified in the subsequent step. As a final step within problem structuring, decision-makers are required to articulate their preferences with respect to the relative importance they place on different decision criteria.

This value system is then usually formalised into an MCDA preference model and is used for comparison and evaluation of alternatives in the second, Problem Analysis stage. As shown in Figure 1 and discussed in more detail in Part II, the approach to preference elicitation and modelling, as well as to identification and comparison of alternatives, will depend on the choice of the MCDA technique. Since decision-making processes are often accompanied by uncertainty related to a number of factors, including the information used to support decision-making, decision-makers' value systems, elicitation and modelling of preference and choice of the MCDA technique, it is necessary to carry out robustness, sensitivity and uncertainty analyses before proceeding to the third and final stage, i.e. Problem Resolution. In this stage, decision-makers make a final choice of their preferred alternative. Optionally, the final stage of the decision-support framework can be extended to include monitoring of the implementation of the chosen alternative and evaluation of the final result. This whole process is iterative, with different stages revisited as more information becomes available during decision analysis.

Therefore, the structure of the framework follows the usual format of the MCDA decision process, developed and described in the vast body of MCDA literature. However, as already mentioned and discussed in more detail below and in Part II, the framework has been adapted to reflect the characteristics of decision-making in the context of sustainable development, addressing in particular two types of situations: corporate and public policy decision-making. Related work has also been carried out by other authors, including De Montis et al. (2000), Basson and Petrie (2001) and Seppälä et al. (2002).

Although the emphasis in this framework is on decision-makers and a facilitator or decision analyst is not explicitly mentioned, it is assumed that, because of the complexity involved, a facilitator will guide decision-makers towards reaching decisions that satisfy their needs.

PROBLEM STRUCTURING

In practice, problems do not present themselves in a structured form, with the key issues and alternatives already identified. Problem structuring is rather a human construct conceived to aid the decision-making process through stakeholder discourse and deliberation. In the framework proposed here, problem structuring involves the following steps (see Figure 1):

1. Identification and involvement of stakeholders;
2. Definition and understanding of the problem;
3. Identification of key sustainability issues;
4. Identification of decision criteria (sustainability indicators);
5. Identification of alternatives; and
6. Elicitation of preferences.

Identification and involvement of stakeholders

Engaging stakeholders and understanding their concerns is a prerogative for sustainable development, so stakeholder identification and involvement is the first and probably the most important step in decision-making in the context of sustainable development. To carry it out successfully, two main questions need to be addressed first:

1. Who are the stakeholders and what are their interests?
2. Should all stakeholders be involved in the decision-making process?

1. The stakeholders and their interests: single and multiple decision-makers

For a better understanding of different stakeholders and to anticipate their behaviour in the decision-making process, it is useful to make a distinction between decision-making situations with single and multiple decision-makers (Cohon 1978; Azapagic and Perdan 2000). The former relate to situations with one decision-maker or a group of decision-makers who share the same interests and preferences about the conflicting objectives of a multiple criteria problem. An example of a single decision-maker situation would be in corporate decision-making, whereby it is assumed that all internal stakeholders, i.e. employees, share the goal of maximising the benefits for the company and hence for themselves. Thus, whilst their individual preferences over different criteria and alternatives may differ, they will probably have similar, often pre-formed and well-articulated preferences for these criteria. Therefore, the decision-making process in these situations is that of identifying the best alternatives that maximise the gain for the company, given the multiple criteria and constraints. These situations will rarely be associated with a conflict of interests.

The second type of decision-making involves situations with many decision-makers and interest groups or stakeholders, each with different or conflicting preferences and objectives. This is particularly the case in the context of sustainable development, and would involve both corporate and public policy decision-making. An example of the former would be decisions that affect both internal and external stakeholders, e.g. a planning application for a new industrial installation. The example of public policy decision-making would be a proposal for a new tax policy or environmental legislation. In addition to often not understanding the value systems of the others, some groups of stakeholders will have difficulties in articulating their own preferences or will perhaps enter the decision-making process without preconceived preferences and will form their opinions during interactions with the other stakeholders. It is, therefore, important to approach these two types of decision-making situations in a way that enables decision-makers to explore and elicit their preferences at different stages of the decision-making process; this issue is discussed in more detail later.

The key for a successful decision-making process is to identify both internal and external stakeholders, as appropriate for the type of decision-making, and to analyse how the outcome of the decision-making process would affect each group, either positively or negatively. This is particularly important in situations with multiple decision-makers, where establishing a dialogue between the stakeholders at an early stage of the decision-making process can help identify areas of potential conflict among the stakeholder groups before they materialise. An example of different stakeholders is given in Table 1, also showing their potential interest in sustainability issues (Azapagic 2003). It is also important to recognise that different stakeholders will have different levels of interest in the particular issues, but also that some stakeholders may have the power to influence a particular decision. Furthermore, interactions between stakeholders are usually very dynamic, where opinions are frequently changed under the influence of others, so that no stakeholder group should be considered in isolation (Eden and Ackermann 1998). An analysis of these interactions may be useful in identifying which stakeholders' views are likely to dominate or influence the decision-making process, but also in choosing the type of MCDA model to be used in the Problem Analysis step of the decision-support framework (see Part II).

Table 1 Stakeholders' interest in different sustainability issues

	Sustainability issues		
Stakeholders	*Economic*	*Environmental*	*Social*
Employees	⊕	+	⊕
Trade unions	⊕	–	⊕
Contractors	⊕	–/+	–/+
Suppliers	⊕	–	–
Customers	⊕	+	+
Shareholders	⊕	+	+
Creditors	⊕	+	+
Insurers	⊕	⊕	⊕
Local communities	⊕	⊕	⊕
Local authorities	⊕	⊕	⊕
Governments	⊕	⊕	⊕
NGOs	+	⊕	⊕

⊕ strong interest; + some interest; – no interest

2. *Stakeholder involvement: a discourse ethics approach*

A question often asked is whether it is desirable or possible to involve representatives of all relevant stakeholder groups in the decision-making process. The need for comprehensive stakeholder inclusion in the decision-making process is argued in many philosophical and social theories, but it is a contention of this paper that the rationale and main support for it can be found in discourse ethics. As argued by Perdan (1998), discourse ethics emphasises the importance of deliberative processes in decision-making, and sees stakeholder deliberation as an essential feature of collective decision-making. According to discourse ethics, in order to reach universally acceptable decisions, the decision-making process has to take into account and mediate by means of argument all different rationales, values and different conflicting claims of the affected parties through an equitable balance among interests. This discursive mediation of conflicting interests and rival perspectives represents both a *legitimising* process and a process whereby the decision can be delivered in an *ethically* acceptable way.

Mediation between the different values and interests of the different stakeholders, on the one hand, and the generally binding decisions and co-responsibility, on the other hand, requires forms of decision-making that support a process of uncoerced and undistorted communicative interaction between different individuals and cultures. What is needed is an open discourse that encourages mutual respect of alternative views and produces shared understanding of the common problems. Only on the basis of mutual recognition and acceptance of others as responsible agents, can a consensus be built on decisions and envisage cooperative agreements among different stakeholders regarding the common interests.

Discursive and deliberative approaches, such as 'Citizens Jury' and 'Group Contingent Valuation' (Jacobs 1997; Stern and Dietz 1994), used most recently in environmental evaluations, follow this normative ideal. They are based on recognition that, where public goods are at issue, deliberative and discursive processes in which people are brought together to debate before making their judgements are the appropriate way of articulating public values. Such a discursive or deliberative approach may have the same purpose as more conventional survey methods, but it may be more reliable, however, because individuals at least have the opportunity to review their preferences in collaborative discussion with others.

The function of discourse ethics with regard to deliberative decision-making processes could be seen as offering a normative model in terms of an ideal procedure of deliberation and decision-making. The procedure itself can be characterised in terms of the following postulates, developed here from re-worked conditions of the ideal speech situation (see Habermas 1990):

1. Practical discourse over an issue that affects different groups of stakeholders should be inclusive and public. No one may be excluded in principle – practical discourse ought to be open to all competent speakers whose interests are, or will be, affected by regulations adopted to resolve the issue.
2. The process of deliberation should take place in argumentative form, that is, through the regulated exchange of information and reasons among parties who introduce and critically test proposals.
3. Deliberations should be free of any external coercion. The participants are autonomous insofar as they are bound only by the presuppositions of communication and rules of argumentation. Existing power differentials between participants have to be neutralised in some way so that they have no bearing on issues within the cooperative pursuit of rational agreement through argumentation.
4. Deliberation should be free of any internal coercion that could detract from the equality of the participants. Each participant should have an equal opportunity to be heard, to make contributions, to suggest and criticise proposals. Participants must be able to adopt a hypothetical stance toward their own interests, values, needs, etc., as well as to those expressed by others.

These postulates specify a procedure for reaching binding decisions that lie in the equal interest of all. Such a procedure should guarantee:

- Inclusion of all those affected;
- Equally distributed and effective opportunities to participate in the decision-making process;
- Equal rights to influence decisions;
- Equal rights to propose alternatives, decision criteria and other aspects that influence decision-making;
- A situation that allows all participants to develop, in the light of sufficient information and good reasons, an articulate understanding of the contested interests.

However, unavoidable social complexity makes it necessary to apply the above principles in a differentiated fashion. Among other things, it requires delegating of decision-making powers and sensitive modification of decision procedures to achieve a practical reduction of complexity.

With regard to the ideal deliberation procedure and fundamental ethical norms, it should be said that they have the character of regulative ideas in the sense employed by Kant. Regulative ideas are normative principles which are binding on action in the sense that they define obligations and provide guidance for the long-term approximate realisation of an ideal. At the same time, however, they give expression to the insight that nothing that can be experienced in time can ever fully accord with the ideal. This means that, at the same time as we recognise these principles, we know that we will be able to realise them only in consideration of many pragmatic restrictions. In practice, of course, the postulates of discourse ethics can be realised in most cases only by means of the representation of interests through some form of advocacy. Any decision-making process that involves different stakeholders must indeed allow for the necessary limitations of time, the differences in stakeholders' competence, the specialisation of discourses according to them, etc. Yet, despite these necessary pragmatic restrictions upon various forms of stakeholder inclusion and deliberative decision-making processes, the idea of finding common ground through an interactive process of discussion and sharing of information, knowledge and experience, remains a valid ethical ideal.

Definition and understanding of the problem

Once the stakeholders have been identified and engaged in the decision-making process, their first task is to define and understand the problem at hand. Whilst it may intuitively be obvious that decision-makers will already be familiar with the decision problem, it is surprising how often that is not the case. Depending on the particular problem in question and on the type of decision-making situation (single or multiple decision-makers), decision-makers may have an idea of what they are trying to achieve, but are unsure of the scope of the problem and its constraints. In other cases, different stakeholder groups will be familiar with key decision issues but will have a different understanding of the same problem. It is therefore important to start problem structuring by asking all relevant stakeholders to define the problem the way they see it and then to share their understanding and ideas in an open dialogue. These interactions will not only encourage generation of ideas that will be useful in the later stages of the decision-making process, but can also help stakeholders to understand each other's position at the outset, so that any misunderstandings can be dealt with in the early stages.

Problem definition normally starts by trying to define the main goal of decision-making at the more general level, followed by identification of specific objectives. For example, in corporate decision-making, the general goal could be to

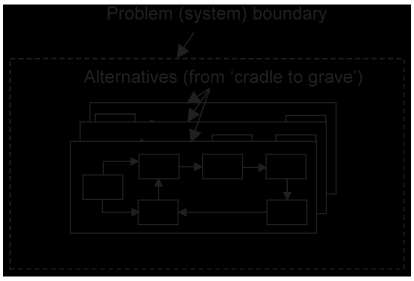

Figure 2 Defining a decision-problem and its boundaries

identify the most sustainable design alternative for a new manufacturing plant. At a more specific level, the objective could be to choose the alternative that is most flexible in terms of the products that can be produced and that minimises costs and environmental impacts. This should be followed by a definition of the scope and the boundaries of the problem or system under investigation and the main constraints that will limit decision choices. As already discussed, in the context of sustainable development, system boundaries should be drawn from 'cradle to grave'. In the example of choosing the most sustainable design of the manufacturing plant, the system boundary would include all relevant activities from extraction and refining of natural resources to make and operate the plant, all the way down to plant decommissioning and waste management. This is illustrated in Figure 2. The number of viable design alternatives that can be considered would normally be limited by a range of constraints, including, for example, the maximum investment and pay-back time, legislative limits on air and water emissions and health and safety concerns.

Problem definition in public policy decision-making may be more complex than in corporate decision-making. An interesting example is the implementation of the EC Packaging Directive in the UK (Nunan 1999), where the UK Government initially tried to promote self-regulation of the packing sector rather than use 'hard' legislation. The process failed because the many players in the complex supply chain could not agree on the goals and objectives of the decision-making problem. For example, while the government thought the objective was to identify a single point of obligation for packaging recovery, nobody from industry would agree to act. Furthermore, while the government was reluctant to legislate, industry wanted it to do so because they were worried about 'free-riders', i.e. those who would not participate in the scheme but would still benefit from it. Ironically, this was the only point on which all players in the supply chain agreed unanimously. Left without much choice, the government decided in the end to abandon the multiple stakeholder decision-making process and to legislate.

Identification of key sustainability issues

Misunderstandings about problem definition are not the only stumbling block for successful decision-making – identification of key sustainability issues and decision criteria can also impede the decision-making process. It is therefore important that at this stage that each group of decision-makers flags the issues that are important to them, as well as finds out which issues matter to the other groups, without trying to elicit any preferences yet. The initial list of issues will probably be longer than is practically possible to handle, but at this stage, no attempt should be made to pair it down as it is important to get an and idea of which issues are important to different stakeholders. At a later stage, when the stakeholders start eliciting their preferences, it will become clear which issues are redundant, but trying to eliminate them at this stage could cause disagreements between different stakeholders and thus hinder decision-making.

Depending on the type of problem and decision-making situation, it might be helpful to refer decision-makers, for example, to the national sustainability strategy and the key sustainability issues specified there. For example, the priority issues identified by the EU sustainability strategy include (EC 2001):

- Poverty and social exclusion;
- Climate change;
- Public health;
- Management of natural resources; and
- Transport congestion and pollution.

To be useful in decision-making, these 'top level' issues have to be disaggregated into 'lower level' criteria; for example, 'management of natural resources' can be described by consumption of fossil fuels, mineral resources and loss of biotic species. Similarly, some industrial sectors have already identified their key sustainability issues through multiple stakeholder consultations (see Table 2), so the results of these findings can be used to facilitate the identification of issues relevant to a particular decision problem.

Identification of decision criteria

In the MCDA theory, decision criteria are referred to as values, objectives, attributes and so on. Decisions in the context of sustainable development are increasingly being made using indicators of sustainable development, so that it is appropriate to define here sustainability indicators as decision criteria. Some decision analysts and MCDA techniques differentiate between criteria and attributes, defining the latter as quantitative measures of performance associated with a particular criterion (see e.g. Belton and Stewart 2002). In that context, quantitative sustainability indicators could be regarded as attributes. Since many of the sustainability indicators are qualitative, for simplicity this distinction is not made in this proposed framework so that all indicators are referred to as criteria.

Table 2 Examples of sustainability issues relevant to industry

Economic issues	*Environmental issues*	*Social issues*
Contribution to GDP and wealth creation	Biodiversity loss	Bribery and corruption
Competitiveness	Emissions to air and water	Employment
Distribution of revenues and wealth	Energy use	Equal opportunities and non-discrimination
Investments	Global warming	Health and safety
Shareholder value	Land use and management	Human rights
Value added	Resource use and availability	Relationship with local communities
	Solid waste	Stakeholder involvement

Sustainable development indicators translate sustainability issues into quantitative or qualitative measures of economic, environmental and social performance. Therefore, the identification of sustainability issues is a useful starting point in identification of sustainability indicators that will be used as decision criteria. Development of sustainability indicators is a subject of ongoing research, both at national and industry levels, and a large body of literature is starting to emerge in this field. For a review of national and industry indicators, see e.g. Moldan et al. (1997) and Azapagic and Perdan (2000), respectively. Table 3 shows an example how environmental issues listed in Table 2 can be translated into relevant indicators. In the context of sustainability decision-making, where there are often a large number of sustainability issues and related indicators, the challenge is to reduce the list of criteria to a number that can be handled by decision-makers. Most MCDA studies suggest that the number of criteria should not exceed ten. In translating the issues into a smaller number of indicators the following should be borne in mind (Belton and Stewart 2002):

- **Value relevance**: decision-makers must be able to relate each indicator to the 'top level' goals they are trying to achieve and to express their preferences or values in relation to these goals.
- **Understandability**: decision-makers must have a shared understanding of concepts and indicators to be used in the decision-making process.
- **Measurability**: if possible, the indicators should be measurable and quantifiable; however, in some cases this is not possible (e.g. ethical considerations) so that appropriate MCDA modelling techniques have to be chosen to deal with qualitative criteria.
- **Non-redundancy**: ideally, each indicator should measure a different factor so that none of the indicators is included in the analysis more than once. To avoid double accounting, if possible, similar indicators should be combined into a single indicator.
- **Judgmental independence**: indicators should be independent of each other so that a preference for one indicator does not depend on the level of another.
- **Balancing completeness and conciseness**: it is important to capture all relevant issues and identify related indicators; however, too much detail may be difficult to handle so that there is a need to balance these two contradicting decision analysis requirements.
- **Operationality**: the amount of information and level of detail captured by the indicators should not place excessive demand on decision-makers.
- **Simplicity vs. complexity**: indicators should be as simple as possible, without becoming too simplistic so that they no longer capture the essence of the identified sustainability issues.

Table 3 Examples of translating environmental issues into indicators

Environmental issues	*Environmental indicators*
Biodiversity loss	Rate of loss of an endangered species
Emissions to air and water	Air emissions of sulphur dioxide Water emissions of heavy metals
Energy use	The amount of energy used
Global warming	Emissions of greenhouse gases
Land use and management	Area of land occupied Rate of land restoration
Resource use and availability	The amount of fossil fuels used The amount of mineral resources extracted
Solid waste	The amount of solid waste generated

Although the above guidelines should be followed as closely as possible, there are no hard and fast rules as to how they should be achieved and will, in many cases, depend on the type of decision problem. Different MCDA modelling techniques may be able to accommodate departures from these requirements. For example, the outranking and goal programming methods, in principle, do not demand judgmental independence. MCDA techniques are discussed in detail in Part II.

Identification of alternatives

Once the decision criteria, i.e. sustainability indicators, have been specified, decision-makers can focus on identifying the alternatives. Although, in principle, it may be possible to identify the alternatives prior to the identification of decision criteria (and in practice this may be a more frequent occurrence), the decision-making process may be more productive if decision-makers first understand which issues and criteria are important and then specify the alternatives. This is particularly important for multiple decision-maker situations, where each party may have brought to the decision table their own alternatives without first understanding what issues are important to the other stakeholder groups. As identification of key sustainability criteria and alternatives are interlinked, these two steps could be carried out in parallel and in an iterative way. As discussed in the following section, in some cases it may be appropriate to elicit preferences for decision criteria prior to the identification of alternatives; however, care should be taken here not to rule out some good alternatives before each alternative has been analysed and its consequences fully understood. To avoid this possibility, the iterative approach may also be required in the elicitation of preferences.

As already noted, in some cases decision-makers will already have identified feasible alternatives but in the others they will have to evolve as a part of the decision-making process. On occasions, the challenge may be to find any suitable alternatives (Belton and Stewart 2002). In most cases, the alternatives will either be relatively few or infinitely many. Strategic decisions, which relate to policies, plans and programmes, will normally deal with a few discrete options, while at the more detailed or operational level related to a particular project decision-makers usually have to make a choice among a large number of options. For example, strategic decisions may be related to formulating a national sustainable energy or public transport policy where there are a relatively few discrete options to choose from. In corporate decision-making, choosing the best (detailed) plant design could be considered an operational decision which normally presents decision-makers with an almost infinite set of feasible design configurations. Decision situations with a large number of options will normally require some sort of screening to reduce the number of alternatives to a more manageable amount. This can be done, for example, by considering all feasible options to identify clusters of similar alternatives and then treating each cluster as one possible decision choice. However, this method requires decision-makers to be already familiar with a large number of alternatives and to have an *a priori* idea of the importance of different decision criteria so that clusters can be identified. This process may also be prohibitively resource- and time-intensive. Another way to screen a large number of feasible alternatives would be to identify optimal or 'satisficing' options from an infinite number of alternatives so that the non-optimal options are eliminated. So-called programming methods are used for these purposes, including multiple objective optimisation (MOO) and Goal Programming (GP). As discussed in Part II, MOO generates a plethora of non-inferior or Pareto optimal (efficient or non-dominated) alternatives in which, by definition, no one alternative dominates (or is better on all criteria than) any other alternative. In GP, the 'satisficing' alternatives are generated with respect to some goal defined by decision-makers. However, discarding the dominant alternatives from analysis is only advisable when the intention is to select one unique decision alternative rather than a combination of options and the set of criteria are complete (Belton and Stewart 2002).

While the programming methods are useful in generating optimum or 'satisficing' solutions, the large number of solutions may make it difficult for decision-makers to choose the preferred alternative. In these cases, it may be necessary to elicit decision-makers' preferences in the post-optimal analysis to help them in their choice of the preferred alternative.

Elicitation of preferences

Following the identification of decision criteria and alternatives, decision-makers face probably the most difficult problem in the decision-making process: identification of individual preferences and value judgements. The process so far has not been value-free either, as each stage, including definition of the goal and scope of the problem and identification of criteria and alternatives, has required some kind of value judgement. However, decision-makers are not until this stage required to articulate their preferences explicitly. In addition to expressing their own preferences, each decision-maker has also to try to understand the preferences of the others participating in decision-making. One of the difficulties with articulation of values is that, in many cases, the value judgements are incompletely formed or do not exist. The main challenge is therefore to help decision-makers to learn about their own preferences but also about the preferences of the other stakeholders. Preferences can be elicited at different stages in the decision-making process:

- Prior to identification of alternatives;
- After identification of alternatives; or
- Iteratively, both before and after identification of alternatives.

The first two approaches may be more suitable for single decision-makers who know exactly which criteria are important to them and what they are aiming to achieve. Iterative identification of preferences may be more suited for multiple decision-makers as it enables different stakeholder groups to gain a better understanding of each other's value system and perhaps correct their position so that a compromise can be reached. Some authors (e.g. Stewart 1992), however, point out that interactive approaches are more open to manipulation by skilled users and may be open to criticism, particularly in situations where decision choices have to be justified to a wider community. Therefore, as discussed in the previous section, it may be more appropriate for multiple decision-makers to elicit their preferences after the feasible alternatives have been identified, as that allows them to examine the trade-offs between different alternatives for each criterion and to see exactly what can be gained and what lost by each alternative. *A priori* articulation of preferences is less suitable in these situations as it can rule out some good alternatives before all the trade-offs have been understood and explored by decision-makers. This may also apply to single decision-makers in cases where preferences for some criteria are unclear and where trading-off can further inform decision-making.

Regardless of when in the decision-making process the preferences are articulated, decision-makers will have to express their preferences for each individual decision criterion, in this context each sustainability indicator, and then subsequently choose the most sustainable alternative based on these value judgements. The elicitation of preference is usually followed in the Problem Analysis stage by construction of an aggregation model to combine the preferences across criteria to allow inter-criteria comparisons or trade-offs. As discussed in Part II, the actual process of preference identification and aggregation will depend on the chosen MCDA technique, but in any case, the outcome of this stage will normally be a 'value tree' which shows a hierarchy of decision criteria as perceived and elicited by decision-makers. An example of a value tree is given in Figure 3. As shown in the figure, the 'top level' goal of choosing the most sustainable option, perched on the 'top' of the tree, is broken down into 'lower level' objectives, i.e. maximising economic, environmental and social benefits by choosing this option. These objectives are disaggregated into the 'bottom level' criteria here represented by the specific sustainability indicators, such as total investment costs, value added, emissions of sulphur dioxide etc. The 'bottom' level criteria must be defined so that they enable ordering of alternatives in terms of each criterion. If this is not the case, then it is necessary to further disaggregate the criteria into their components or perhaps to redefine them altogether.

There are two general approaches to building value trees: top-down and bottom-up (von Winterfeldt and Edwards, 1986). The top-down approach begins with a general statement of the overall goal and the objectives which are then disaggregated into more specific measures of performance, i.e. sustainability indicators. In the bottom-up approach, the detailed criteria are specified first, stimulated by thinking about the strength and weaknesses of available alternatives (Belton and Stewart, 2002). Keeney (1992) terms these two respective approaches as value-focused and alternative-focused. There is no 'right' approach to building the value tree; what matters here is that the outcome of this stage of the analysis should be a value tree that captures the decision makers' values. In most single decision-makers situations it will be possible to map preferences on one, shared value tree. However, in cases with multiple decision-makers, it will be necessary to construct different value trees for different groups of stakeholders to describe their different value systems.

The issue of relative importance of each of the criteria is fundamental to any MCDA problem. Typically, some form of numerical score or weight parameter is used in most MCDA techniques to model relative importance of criteria, usually on a scale of 0–1 or 0–100. The example shown in Figure 3 shows a set of hypothetical weights allocated to different sustainability objectives and indicators on a scale 0–1. Thus, in this hypothetical example, for the overall goal of 'choosing the most sustainable option', the economic, environmental and social objectives have a relative importance of 0.4, 0.3 and 0.3 respectively. With respect to the environmental benefits alone, biodiversity loss has

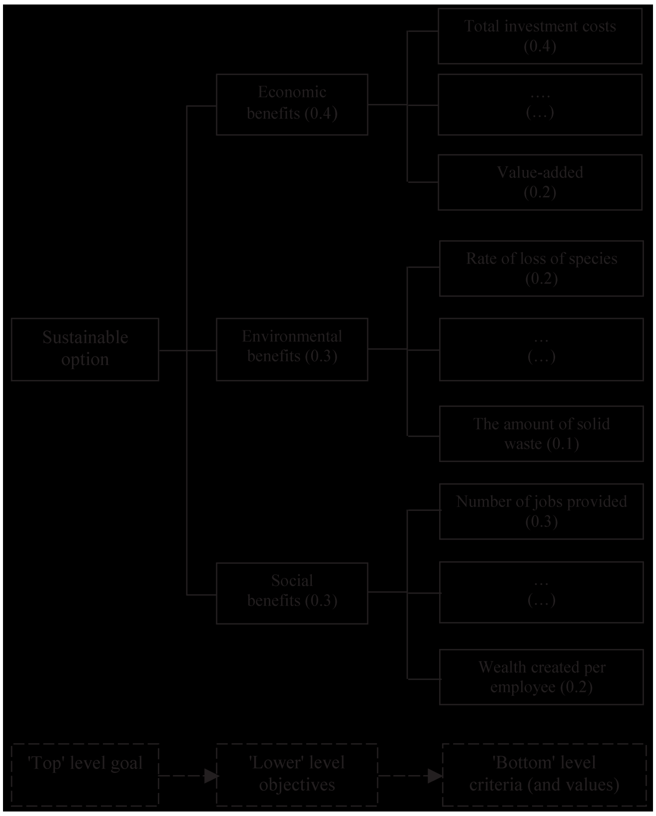

Figure 3 An example of a 'value tree' and (hypothetical) preferences for different sustainability objectives and criteria

been assigned a relative importance of 0.2, while solid waste carries the weight of 0.1.

It is important to bear in mind that the meaning of the numerical weight parameter will differ according to the particular preference model being used and according to the range of alternatives under consideration. Similarly, it would be wrong to assume that the weight parameters will have any meaning outside a particular decision context. For example, in environmental decision analysis, it has often been suggested that it is possible to derive a universally applicable set of weights of importance of different environmental impacts and that these could be used in general public policy making. However, many attempts to derive such a set of weights have so far universally failed, each time re-confirming that subjective value judgements can only be derived and interpreted within a particular decision context and that outside that context they have little or no meaning. The interpretation of weights is discussed further in Part II of this paper, together with the MCDA methods that can be used to help interpret decision maker preferences and choose the most sustainable option from a set of alternatives.

CONCLUSIONS

Due to complexity, decision-making problems in the context of sustainable development must be approached in an integrated and systematic way. The multiple criteria decision-support framework proposed in this paper is based on such an approach, with the aim of facilitating both corporate and public policy decision-making. The framework can be used in situations with single or multiple decision-makers who need to reach either a strategic or operational type of decision. It can guide the decision-making process by providing structure to the debate, ensuring communication among decision-makers, and understanding each other's value systems. Problem Structuring, the first of three stages of the framework, guides decision-makers through problem definition, identification of decision criteria and alternatives and elicitation of preferences. In the second, Problem Analysis stage, described in Part II, decision-makers are guided in their choice of the most sustainable solution. In this way, the framework can facilitate 'good' decision-making by helping decision-makers to understand better the decision problem and the consequences of their decision for sustainable development.

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