International Society for Ecological Economics
Internet Encyclopaedia of Ecological Economics

Multicriteria Assessment

Giuseppe Munda

February 2003

1. Introduction

In empirical evaluations of public projects and public provided goods, multi-criteria decision theory seems to be an adequate policy tool since it allows taking into account a wide range of assessment criteria (e.g. environmental impact, distributional equity, and so on) and not simply profit maximisation, as a private economic agent would do (Arrow and Raynaud, 1986; Martinez-Alier et al., 1998). As a tool for conflict management, multi-criteria evaluation has demonstrated its usefulness in many environmental policy and management problems (see e.g. Beinat and NIjkamp, 1998; Janssen and Munda, 1999; Munda, 1995; Nijkamp et al., 1990; Romero and Rehman, 1989).

From an operational point of view, the major strength of multi-criteria methods is their ability to revolve questions characterised by various conflicting evaluations thus allowing an integrated assessment of the problem at hand. A typical multi-criteria problem (with a discrete number of alternatives) may be described in the following way: A is a finite set of n feasible actions (or alternatives); m is the number of different points of view or evaluation criteria g_i i=1, 2, ... , m considered relevant in a decision problem, where the action **a** is evaluated to be better than action **b** (both belonging to the set A) according to the i-th point of view if $g_i(a)>g_i(b)$. In this way a decision problem may be represented in a tabular or matrix form. Given the sets A (of alternatives) and G (of evaluation criteria) and assuming the existence of n alternatives and m criteria, it is possible to build an n x m matrix P called evaluation or impact matrix whose typical element p_{ij} (see Table 1) (i=1, 2 , ... , m; j=1, 2 , ... , n) represents the evaluation of the j-th alternative by means of the i-th criterion. The impact matrix may include quantitative, qualitative or both types of information (Munda et al., 1994).

In general, in a multi-criteria problem, there is no solution optimising all the criteria at the same time and therefore compromise solutions have to be found. However, one should note that when different conflicting evaluation criteria are taken into consideration, a multi-criteria problem is mathematically ill-defined. The consequence is that a complete axiomatization of a multi-criteria aggregation convention i.e. a multi-criteria method is quite difficult (Arrow and Raynaud, 1986). As a consequence, a wide set of multi-criteria methods exists (Bana e Costa, 1990; Keeney and Raiffa, 1976; Munda, 1985; Roy, 1996; Saaty, 1980; Vincke, 1992; Zeleny, 1982). To deal with this issue two main approaches can be distinguished.

1. The attempt of checking under which specific circumstances each method could be more useful than others, i.e. the search of the right method for the right problem (e.g., see Guitouni and Martel, 1998).

2. The attempt of looking for a complete set of formal axioms that can be attributed to a specific method (e.g., Arrow and Raynaud, 1986).

		Alternatives			
Criteria	**Units**	$\mathbf{a_1}$	$\mathbf{a_2}$	$\mathbf{a_3}$	$\mathbf{a_4}$
$\mathbf{g_1}$		$g_1(a_1)$	$g_1(a_2)$	.	$g_1(a_4)$
$\mathbf{g_2}$		.	.	.	.
$\mathbf{g_3}$		.	.	.	.
$\mathbf{g_4}$		.	.	.	.
$\mathbf{g_5}$		.	.	.	.
$\mathbf{g_6}$		$g_6(a_1)$	$g_6(a_2)$	.	$g_6(a_4)$

Table 1. Example of an Impact Matrix

In order to address contemporary issues economics needs to expand its empirical relevance by introducing more and more realistic (thus more complex) assumptions in its models. One of the most interesting research directions in the field of public economics is the attempt to introduce political constraints, interest groups and collusion effects explicitly (see e.g. Laffont, 2000). In this context, transparency becomes an essential feature of public policy processes (Stiglitz, 2002).

Social multi-criteria evaluation (SMCE) has been explicitly designed to enhance transparency; the main idea being that results of an evaluation exercise depends on the way a given policy problem is represented and thus the assumptions used, the interests and values considered have to be made clear (Munda, 2003).

2. The Issue of Representation of Real-World Complex Systems and the Incommensurability Principle

The world is characterised by deep complexity. This obvious observation has important implications on the manner policy problems are represented and decision-making is framed. Each representation of a complex system is reflecting only a sub-set of the possible representations of it. A system is then complex when the relevant aspects of a particular problem cannot be captured when using a single perspective (Funtowicz et al., 1999; O'Connor et al., 1996).

To make things more difficult, systems including humans are reflexively complex. Reflexive systems present two peculiar aspects: “awareness” and “purpose”, both requiring an additional “jump” in describing complexity. The presence of self-consciousness and purposes (reflexivity) means that these systems can continuously add new relevant qualities/attributes that should be considered when explaining, describing or forecasting their behaviour (i.e. human systems are learning systems).

Moreover, the existence of different levels and scales at which a hierarchical system can be analyzed implies the unavoidable existence of non-equivalent descriptions of it (Giampietro, 1994). Even a simple “objective” description of a geographical orientation is impossible without taking an arbitrary subjective decision on the system scale considered relevant. In fact the same geographical place, e.g., in the USA, may be considered to be in the north, south, east or west according to the scale chosen as a reference point (the whole USA, a single state and so on) (Giampietro and Mayumi, 2000).

Therefore, the problem of multiple-identities in complex systems cannot only be interpreted in terms of epistemological plurality (non-equivalent observers), but also in terms of ontological characteristics of the observed system (non-equivalent observations). A consequence of these deep subjectivities is that in any normative exercise connected to a social decision problem, one has to choose an operational definition of "value" in spite of the fact that social actors with different interests, cultural identities and goals have different definitions of "value" (O'Neill, 1993). That is, to reach a ranking of policy options, there is a previous need for deciding about what is important for different social actors as well as what is relevant for the representation of the real-world entity described in the model. One should note that the representation of a real-world system depends on very strong assumptions about (1) the purpose of this construction, e.g. to evaluate the sustainability of a given city, (2) the scale of analysis, e.g. a block inside a city, the administrative unit constituting a municipality or the whole metropolitan area and (3) the set of dimensions, objectives and criteria used for the evaluation process. A reductionist approach for building a descriptive model can be defined as the use of just one measurable indicator (e.g. the monetary city product per person), one dimension (e.g. economic), one scale of analysis (e.g. the Commune), one objective (e.g. the maximisation of economic efficiency) and one time horizon.

An outcome of this discussion is that the political and social framework must find a place in multi-criteria decision theory. To give an example; in Spain about 40 years ago, there was an important policy criterion: safety of the north frontier with France. Nowadays nobody even remembers the existence of this Franco's attitude towards frontiers. In fact, policy criteria are the consequence of the social and political framework existing in a given historical period. To give another example, at the moment the environmental dimension is becoming more and more important in evaluation projects while this was almost irrelevant 40 years ago.

In general, these concerns have not been considered very relevant by scientific research in the past (where the basic implicit assumption was that time was an infinite resource). On the other hand, the new nature of the policy problems faced in this third millennium (e.g., the mad cow, genetic modified organisms, …), implies that very often when using science for policy-making, long term consequences may exist and scientists and policy-makers are confronting issues where, "facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz and Ravetz, 1991, 1994). In this case, scientists cannot provide any useful input without interacting with the rest of society and the rest of the society cannot perform any sound decision making without interacting with the scientists. That is, the question on "how to improve the quality of a policy process" must be put, quite quickly, on the agenda of "scientists", "decision makers" and indeed the whole society.

The previous discussion can be synthesised by using the philosophical concept of weak comparability (Martinez-Alier et al., 1998; O'Neill, 1993). Weak comparability implies incommensurability i.e. there is an irreducible value conflict when deciding what common comparative term should be used to rank alternative actions. Remembering that the presence of multiple-identities in complex systems can be explained in terms of epistemological plurality and in terms of ontological characteristics of the observed system, it is possible to further distinguish the concepts of social incommensurability and technical incommensurability (Munda, 2003). Social incommensurability can be derived from the concepts of reflexive complexity and Post Normal Science and refers to the existence of a multiplicity of

legitimate values and interests in society. Technical incommensurability comes from the multidimensional nature of complexity and refers to the issue of representation of multiple identities in descriptive models.

If one wants to implement technical incommensurability, there is a clear need to take into account incommensurable dimensions using different scientific languages coming from different legitimate representations of the same system. This is what Neurath (1973) called the need for an "orchestration of sciences". From the experience made in various real-world case studies, it has been learnt that the use of a multi-criterion framework is a very efficient tool to make Neurath's idea operational. Here I refer to the idea of orchestration of sciences as a combination of multi/inter-disciplinarity (multi-disciplinarity: each expert takes her/his part; inter-disciplinarity: methodological choices are discussed across the disciplines). In terms of inter-disciplinarity, the issue is to find an agreement on the set of criteria to be used; in terms of multi-disciplinarity, the issue is to propose and compute an appropriate criterion score.

To deal with social incommensurability, there is a need to consider the public participation issue. For the formation of contemporary public policies, it is hard to imagine any viable alternative to what Funtowicz and Ravetz call extended peer communities (Corral-Quintana et al., 2001; De Marchi and Ravetz, 2001; Gowdy and O'Hara, 1996).

3. From Multi-Criteria Decision Making (MCDM) to Social Multi-Criteria Evaluation (SMCE)

Historically the first stage of the development of multi-criteria decision theory was characterized by the so-called methodological principle of multi-criteria decision making (MCDM) whose main aim is to elicit clear subjective preferences from a mythical decision-maker (DM) and then try to solve a well-structured mathematical decision problem thanks to a more or less sophisticated algorithm. In this way a multi-criterion problem can be still presented in the form of a classical optimisation problem (Keeney and Raiffa, 1976). The limitations of the classical concept of an optimum solution and the consequential importance of the decision process has recently been emphasised in the context of the decision sciences by authors such as H. Simon and B. Roy.

According to Simon (1976), a distinction must be made between the general notion of rationality as an adaptation of available means to ends, and the various theories and models based on a rationality which is either substantive or procedural. This terminology can be used to distinguish between the rationality of a decision considered independently of the manner in which it is made (in the case of substantive rationality, the rationality of evaluation refers exclusively to the results of the choice) and the rationality of a decision in terms of the manner in which it is made (in the case of procedural rationality, the rationality of evaluation refers to the decision-making process itself). "A body of theory for procedural rationality is consistent with a world in which human beings continue to think and continue to invent: a theory of substantive rationality is not" (Simon 1976).

Roy (1985, 1990, 1996) states that in general it is impossible to say that a decision is a good one or a bad one by referring only to a mathematical model: all aspects of the whole decision process which leads to a given decision also contribute to its quality and success. Thus, it becomes impossible to find the validity of a procedure either on a notion of approximation (i.e. discovering pre-existing truths) or on a mathematical property of convergence (i.e. does the

decision automatically lead, in a finite number of steps, to the optimum a*?). The final solution is more like a "creation" than a discovery. In Multiple-Criteria Decision Aid (MCDA) (Roy, 1985), the principal aim is not to discover a solution, but to construct or create something which is viewed as liable to help "an actor taking part in a decision process either to shape, and/or to argue, and/or to transform his preferences, or to make a decision in conformity with his goals" (Roy 1990) (constructive or creative approach).

The need of public participation has been more and more recognized in a multi-criteria decision-aid framework. Two recent proposals have been participatory multi-criteria evaluation (Banville et al., 1998) and social-multi-criteria evaluation (Munda, 2003). Social multi-criteria evaluation agrees on the need of extending MCDA by incorporating the notion of stakeholder; this is the reason why a social multi-criteria process must be as participative and as transparent as possible; although, it is further argued that participation is a necessary condition but not a sufficient one. This is the main reason why the concept of “Social Multi-criteria Evaluation” (SMCE) is proposed in substitution of “Participative Multi-criteria Evaluation” (PMCE) or “Stakeholder Multi-criteria Decision Aid” (SMCDA).

In my opinion, one should not forget that even a participatory policy process could always be conditioned by heavy value judgements. Have all the social actors the same importance (i.e. weight)? Should a socially desirable ranking be obtained on the grounds of the majority principle? Should some veto power be conceded to the minorities? Are income distribution effects important?

A clear example of the difference between MCDM, MCDA, PMCE and SMCE can be found in the determination of criterion weights. While in a MCDM and MCDA frameworks a relationship is supposed between an analyst and a decision-maker, this is no longer true in PMCE and SMCE, where a need to interact with the whole social framework exists.

A basic point of SMCE is that in society there are different legitimate values and points of view. This creates social pressure for taking into account various policy dimensions, e.g. economic, social and environmental. These dimensions are then translated, by analysts, into objectives and criteria. At this point a question arises, who should attach criterion weights and how? To answer this question we have to accept a basic assumption: to weigh different criteria implies to give weights to different groups in society. This assumption has as main consequence that in social decision processes, weights cannot be derived as inputs coming from participatory techniques. This is technically very difficult (e.g., which elicitation method has to be used? Which statistical index is a good synthesis of the results obtained? Do average values of weights have meaning at all?), pragmatically not desirable (since strong conflicts among the various social actors are very probable to occur) and even ethically unacceptable.

Let’s imagine the case where a development project in the Amazon forest will affect an indigenous community with little contact with other civilizations yet. Would it be ethically more correct to invite them in a focus group… or take into account the consequences of the project for their survival? Thus a plurality of ethical principles (e.g., economic development attaching more weight to the economic dimension, precautionary principle giving a bigger weight to the environmental dimension or sustainability which might imply an equal weighting of all the dimensions) seems the only consistent way to derive weights in a SMCE framework.

The main principles of Social Multi-criteria Evaluation can be summarised as follows (Munda, 2003) (see Figure 1):

(1) One should not forget that the classical schematised relationship decision-maker/analyst is indeed embedded in a social framework, which is of a crucial importance in the case of public policy.

(2) The combination of various participatory methods, which has been proved powerful in sociological research, becomes even more so when integrated with a multi-criterion framework (De Marchi et al., 2000).

(3) The use of a cyclic evaluation process allows incorporating the concept of learning of the scientific team on the case study tackled. It is extraordinary important that different participatory and interaction tools are used in different points in time. This allows for continuous testing of the assumptions used.

(4) According to the geographical scale chosen, the relevant social actors with an interest at stake can be found thanks to institutional analysis. Institutional analysis is an essential step to identify possible "stakeholders" for a participative process. However, besides the unavoidable mistakes that may happen in carrying out an appropriate institutional analysis, there are even stronger reasons why it is not desirable to do a pure participatory study:

a) In a focus group, powerful stakeholders may influence deeply all the others.

b) Focus groups are never meant to be a representative sample of population. As a consequence, they can be a useful instrument to improve the knowledge of the scientific team of the institutional and social dimensions of the problem at hand, but never a way for deriving consistent conclusions on social preferences.

c) The notion of stakeholder only recognises relevant organised groups and not any possible social actor.

d) Since decision-makers search for legitimacy of the decisions taken, it is extremely important that public participation or scientific studies do not become instruments of political de-responsibility. Social participation does not imply that scientists and policy-makers have no responsibility of policy actions defended and eventually taken. As a consequence, ethics matters.

(5) In this framework, mathematical algorithms still play an important role, i.e. to assure that the policy rankings obtained are consistent with the information and the assumptions used. For this reason multi-criteria algorithms to be used in a social context should be as simple as possible (i.e. with the minimum number of exogenous parameters) and that their axiomatization should be complete and clear. Of course in a framework different than SMCE, e.g. stock exchange investments, these properties can easily be irrelevant or even undesirable.

4. Conclusion

In conclusion, we can say that SMCE supplies a powerful framework for public choice since it accomplishes the goals of being inter/multi-disciplinary (with respect to the research team), participatory (with respect to the local community) and transparent (since all criteria are presented in their original form without any transformations in money, energy or whatever common measurement rod).

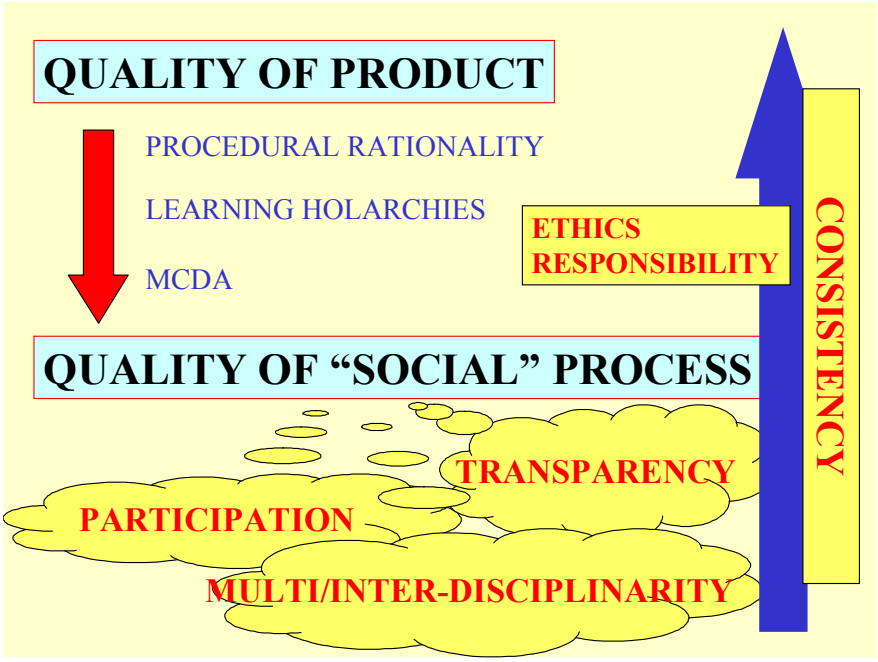

Figure 1. Synthesis of a Social Multi-Criteria Evaluation Process

References

Arrow K.J., Raynaud H. (1986) - Social choice and multicriterion decision making, M.I.T. Press, Cambridge.

Bana e Costa C.A. (ed.) (1990) - Readings in multiple criteria decision aid, Springer-Verlag, Heidelberg.

Banville C., Landry M., Martel J.M., Boulaire C. (1998) – A stakeholder approach to MCDA, Systems Research and Behavioral Science, Vol. 15, pp. 15-32.

Beinat E. Nijkamp P. (eds.) (1998) - Multicriteria evaluation in land-use management: methodologies and case studies, Kluwer, Dordrecht.

Corral-Quintana, S., B. De Marchi, S. Funtowicz, G, Gallopín, Â. Guimarães-Pereira A., B. Maltoni (2001) - The Visions Project at the JRC, European Commission, Joint Research Centre, Institute for the Protection and Safety of the Citizens, EUR 19926 EN [http://alba.jrc.it/visions]

De Marchi B., Funtowicz S.O., Lo Cascio S., Munda G. (2000) – Combining participative and institutional approaches with multi-criteria evaluation. An empirical study for water issue in Troina, Sicily, Ecological Economics, vol. 34 No. 2, pp. 267-282.

De Marchi B., Ravetz J. (2001) – Participatory approaches to environmental policy, Concerted Action EVE, Policy Research Brief, No. 10.

Funtowicz S.O., Ravetz J. R. (1991) - A new scientific methodology for global environmental issues, in R. Costanza (ed.)- Ecological Economics, New York, Columbia, pp. 137-152.

Funtowicz S.O., Ravetz J. R. (1994) - The worth of a songbird: ecological economics as a post-normal science, Ecological Economics, 10, pp.197-207.

Funtowicz S., Martinez-Alier J., Munda G. and Ravetz J. – (1999) Information tools for environmental policy under conditions of complexity, European Environmental Agency, Experts' Corner, Environmental Issues Series, No. 9.

Giampietro, M. (1994). Using hierarchy theory to explore the concept of sustainable development. Futures 26 (6): 616-625.

Giampietro M., Mayumi K. (2000) – Multiple-scale integrated assessment of societal metabolism: introducing the approach, Population and Environment, Vol. 22, No. 2, pp. 109-154.

Giampietro M., Mayumi K. (2000) – Multiple-scale integrated assessment of societal metabolism: integrating biophysical and economic representations across scales, Population and Environment, Vol. 22, No. 2, pp. 155-210.

Gowdy, J.M., and O'Hara S. (1996) - Economic Theory for Environmentalists. Saint Lucie Press.

Guitouni A., Martel J.M. (1998) – Tentative guidelines to help choosing an appropriate MCDA method, European Journal of Operational Research, 109, pp. 501-521.

Janssen R., Munda G. (1999) - Multi-Criteria Methods for quantitative, qualitative and fuzzy evaluation problems, in van den Bergh J. (ed.) – Handbook of environmental and resource economics, Edward Elgar, Cheltenham, pp. 837-852.

Keeney R., Raiffa H. (1976) - Decision with multiple objectives: preferences and value trade-offs, Wiley, New York.

Laffont J.J. (2000) – Incentives and political economy, Oxford University Press, Oxford.

Martinez-Alier J., Munda G., O'Neill J. (1998) – Weak comparability of values as a foundation for ecological economics, Ecological Economics, 26, pp. 277-286.

Munda G., Nijkamp P. and Rietveld P. (1994) - Qualitative multicriteria evaluation for environmental management, Ecological Economics, 10, pp. 97-112.

Munda G. (1995) - Multicriteria evaluation in a fuzzy environment. Theory and applications in ecological economics, Physica-Verlag, Contributions to Economics Series, Heidelberg.

Munda G. (2003) – "Social multi-criteria evaluation (SMCE)": methodological foundations and operational consequences, forthcoming in European Journal of Operational Research.

Neurath O. (1973) – Empiricism and sociology, Reidel, Dordrecht.

Nijkamp, P., Rietveld P. and Voogd H. (1990) - Multicriteria Evaluation in Physical Planning, Amsterdam: North-Holland.

O'Connor M., Faucheux S., Froger G., Funtowicz S.O., Munda G. (1996) - Emergent complexity and procedural rationality: post-normal science for sustainability, in R. Costanza, O. Segura and Martinez-Alier J. (eds.) -Getting down to earth: practical applications of ecological economics, Island Press/ISEE, Washington D.C., pp. 223-248.

O'Neill, J. (1993) - Ecology, Policy and Politics, Routledge, London.

Romero C., Rehman T. (1989) – Multiple criteria analysis for agricultural decisions, Elsevier, Amsterdam.

Roy B. (1985) - Méthodologie multicritère d'aide à la décision, Economica, Paris.

Roy B. (1990) - Decision aid and decision making, in Bana e Costa C.A. (ed.)- Readings in multiple criteria decision aid, Springer-Verlag, Heidelberg, pp. 17-35.

Roy B. (1996) - Multicriteria methodology for decision analysis, Kluwer, Dordrecht.

Saaty T.L. (1980) - The analytic hierarchy process, McGraw Hill, New York.

Simon H.A. (1976) - From Substantive to procedural rationality. In: J.S. Latsis (Editor) Methods and appraisal in economics, Cambridge: Cambridge University Press.

Stiglitz J. E. (2002) – New Perspectives on public finance: recent achievements and future challenges, Journal of Public Economics, 86, pp. 341-360.

Vincke Ph. (1992) - Multicriteria decision aid, Wiley, New York.

Zeleny M. (1982) - Multiple criteria decision making, McGraw Hill, New York.