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Ministry of Water Resources

General Directorate for Water Resources Management

Strategy for Water and Land Resources in Iraq

Guidance Note Series

Multi-criterion Decision Analysis and Models Introductory Explanation

GN 01

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This document is one of a series of occasional guidance notes published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The guidance note gives an introductory explanation of Multi-criterion decision analysis (MCDA), a set of methods which aims to help decision makers when they are faced with several, sometimes conflicting, objectives.

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Abbreviations

MCDA	multi-criterion decision analysis
MCDM	multi-criterion decision model

1 Introduction

1.1.1 Multi-criterion decision analysis (MCDA) is a set of methods aimed at helping decision-makers faced with several objectives which sometimes conflict with each other. This appendix seeks to explain briefly the nature and main features of MCDA, to give references to more detailed information, and to describe one particular type of multi-criterion decision model (MCDM).

1.1.2 In general, a decision-making problem or situation will usually involve:

- A number of alternative courses of action (called alternatives, projects, schemes, plans, options, variants, interventions or packages);
- A number of objectives or criteria;
- A number of stakeholders: one or more persons or groups of people to whom the criteria matter to some degree.

1.1.3 Decision-guiding methods that cover more than one objective or criterion can be complex or simple. A large body of literature has built up, a good summary being in Belton & Stewart 2002, while a briefer account, with reference to water resources, is in Snell 1997[1]. Applications to dams and water resources are described in WCD 2000, and recent theoretical refinements are set out in ISMCDM 2006.

1.1.4 In many situations there is a distinction between the decision-makers, who represent (perhaps imperfectly) all the stakeholders, and on the other hand one or more facilitators or analysts, who help the decision-makers to set up whatever methods or models are being used. These facilitators or analysts form a sort of secretariat to the decision-makers: they administer the model, advise on methodology, do the routine collection and handling of necessary data about projects and options, and keep the records of reasons for decisions. They do not take the decisions.

1.1.5 This Guidance Note begins with general concepts and a very brief review of available methods, then Section 6 introduces a model suitable for allocation of public sector investment funds, and Section 7 describes how it could be used. Some information on experience with MCDM is in Section 8.

[1] The field is referred to under several names, like multi-criteria analysis, multi-criterion decision support, or multi-attribute analysis. Methods are variously called multi-criterion decision aids, multi-criterion decision models, or multi-criterion decision support systems.

2 The Importance of Transparency

2.1.1 If decision-makers do not understand the analysis by which their decisions are guided, they are unlikely to "own" the decisions, and the decisions are unlikely to be effectively implemented. Similarly, if other affected people or groups are not clearly informed of the reasoning behind a proposal, they cannot give it effective consent nor act to improve it. Once a decision has been made, it usually has to be explained and defended to a wider audience, so that a process of communication and persuasion must follow the decision-making. So a decision aid must often serve as an instrument not only of analysis but also of communication and persuasion. Therefore one of its most important characteristics must be transparency. If an analyst collects, processes and analyses information, he must then present a clearly argued case to the decision-makers and other people who are to be consulted. All these people must understand the analysis well enough to influence it, asking the analyst to modify it until they are comfortable with it, so that its results are their decisions, not those of the analyst. A non-transparent analysis can hide undeclared priorities and biases in a "black box" which is either not described at all or described in impenetrable technical jargon; such an approach is not conducive to good decisions that will be followed through and implemented.

3 Screening, Ranking, Thresholds and Dominance

3.1.1 Screening and ranking are two basic and complementary processes used to reduce a long list of conceivable courses of action or alternatives to one preferred alternative, or to a preferred set of alternatives that matches a budget or any other constraint.

- **Screening**, by analogy with a sieve that lets some items through and holds others back, is the simpler: an alternative is either accepted or rejected at a screening phase. It might be rejected by being shown to be totally unacceptable under just one criterion (this is referred to below as a veto), or just by falling below some threshold based on one or several criteria.

- **Ranking** is more subtle than screening in that alternatives are not merely sorted into two classes, the accepted and the rejected, but are placed in order of merit, by whatever measure of merit or preference is being used.

3.1.2 If the degree of the decision-makers' preferences between alternatives is known, then presentation of a ranked order involves a loss of information. For example, suppose three alternatives A, B and C achieve the values 8, 5 and 9 respectively, on some merit or preference scale. One can say that the respective ranks are 2, 3, 1, or that the rank order is C, A, B. Either way one is omitting significant information, namely the fact that the preference for C over A is by only one unit of preference, while A is preferred to B by a margin of three units.

3.1.3 If one alternative is preferred to another under every single criterion, the first is said to dominate the second. It is usually not wise to reject all dominated alternatives before analysing tradeoffs[2].

[2] Belton & Stewart 2002: Section 4.1, page 83.

4 Methods of Multi-criterion Decision Analysis

4.1.1 There are three main groups of methods for MCDA, or multi-criterion decision models (MCDMs)[3]:

- *Value measurement* theory arrives at a number or index value for each alternative, which represents the overall degree of preference for that alternative in the eyes of the decision-makers, using several criteria simultaneously and dealing explicitly with tradeoffs between criteria.

- *Satisficing methods* take one criterion at a time and use it to screen a list of alternatives, then apply another criterion to screen among the remaining alternatives, until a decision guide is reached. Tradeoffs between criteria are not explicitly handled. This is more a description of how people sometimes make decisions with limited information than a recommended method, though it can be useful for initial screening of a large number of alternatives.

- *Outranking methods* extend the concept of dominance to analyse pairs of alternatives to see if one is preferable (outranks the other) strongly, or weakly, or if preference between the two is indeterminate.

[3] Belton & Stewart 2002: Sections 4.2 and 4.3 for value measurement theory, Section 4.4 for satisficing, and Section 4.5 for outranking. Section F.5 of Snell 1997 has a longer list.

5 Uncertainty and Incomplete Information

5.1.1 Decision-makers never have complete and precise information about the available alternatives or their merits under various criteria, nor about the relative importance of the criteria. As well as partial information, there are usually divergences between the preferences or value judgements of the different decision-makers or stakeholders. Any kind of MCDA, to be useful for real decisions, must deal with these uncertainties and divergences[4].

5.1.2 Some experts have developed ways of using fuzzy set theory and rough set theory (lower and upper bounds) to deal with uncertainty, while the satisficing and outranking approaches have their own internal ways of dealing with it[5].

5.1.3 A common and useful way of dealing with uncertainty is to do sensitivity tests. After a model or computation has been set up with the most likely value of each important input parameter, it can be re-run with different values to see what difference each change makes. This can guide the iterative improvement of the model, and if decision-makers are involved at successive stages it can help them to formulate their preferences clearly and to reach a consensus view[6]. The iterative process is described further in Section 7 below.

[4] A discussion of uncertainty in this context is in Section 3.4.4 of Belton & Stewart 2002.

[5] Belton & Stewart 2002: Section 4.6.

[6] Belton & Stewart 2002: Section 5.1 includes the remark that “the learning and understanding which results from engaging in the whole process of analysis is far more important than the numerical results”, and “the process is a constructive one, helping decision-makers to build a model of their values”.

6 The Weighted-Average Model

6.1.1 Among the various methods and models for MCDA, one is preferred here because of its simplicity and transparency, although it can handle complex problems with large numbers of competing alternatives. It is called the additive model within multi-attribute value theory, or the weighted-average model[7]. It is particularly suitable for handling tradeoffs between criteria, for large numbers of alternatives, and for situations where new alternatives may from time to time be added to the list. Because of its simplicity it is easy to explain to decision-makers and other stakeholders.

6.1.2 To set up a model (a MCDM) of this kind it is necessary to define a set of criteria and to assign a relative importance weight to each one. The model also needs a value function or scoring rule for each criterion, and in practice the formulation of the scoring rule provides the precise definition of the criterion. The scoring rule describes how a score is assigned to each alternative under each criterion, usually on a scale from zero to 100 with 100 at the preferred end of the scale. The model operates on a set or long-list of alternatives, each of which is assigned a score under each criterion.

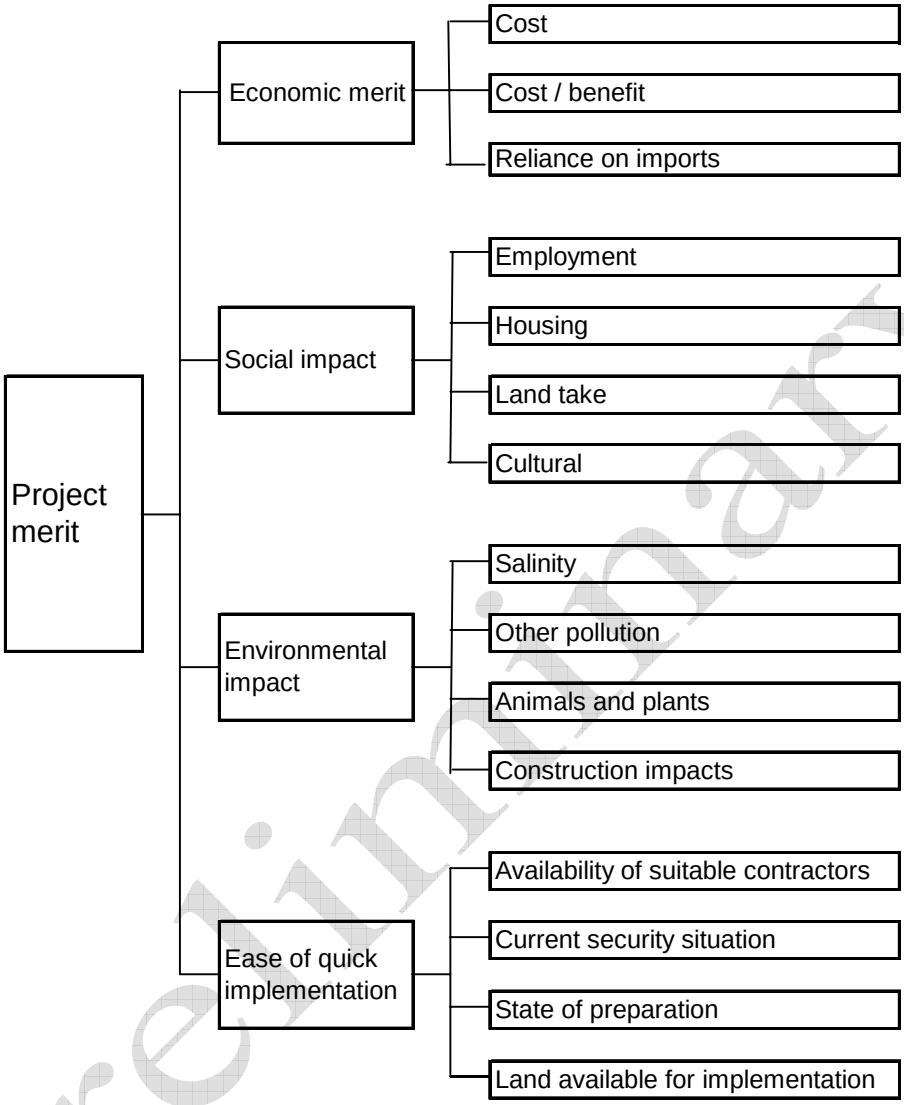
6.1.3 Once these elements are in place (the set of criteria, their weights and scoring rules, and the list of alternatives), the model works by computing an overall merit index value for each alternative. The index value of an alternative is simply the weighted average of its scores under the individual criteria, using the criterion importance weights. When the merit index values have been computed, the alternatives can, if desired, be ranked and sorted to give a priority list, those with high index values at the top of the list. This prioritised list can then be used to draw up investment programmes to match annual budgets or other constraints.

6.1.4 The two setting-up processes, weighting and scoring, are not independent of each other, and the whole model needs to be developed in an iterative manner, trying out early versions with real alternatives, before it gives a good representation of the decision-makers' preferences and value judgements.

6.1.5 A useful device for developing a set of criteria and their importance weights is a 'value tree', which describes a hierarchy of objectives grouped at two or more levels[8]. Figure 1 shows an example of a value tree that might be used for guiding decisions about irrigation projects that compete for limited funds.

[7] Belton & Stewart 2002 Chapter 5; Snell 1997 Section 5.4. Multi-attribute value theory is sometimes called multi-attribute utility theory.
[8] Belton & Stewart 2002, pages 66, 80-81, and 139-141.

Figure 1: An Example of a Value Tree



6.1.6 This one has three levels, though in practice a criterion can be subdivided at a fourth level. The fifteen third-level criteria are grouped into four groups at the second level, which makes the model easier to develop, to use and to explain than if the fifteen criteria had been shown directly contributing to the first-level objective.

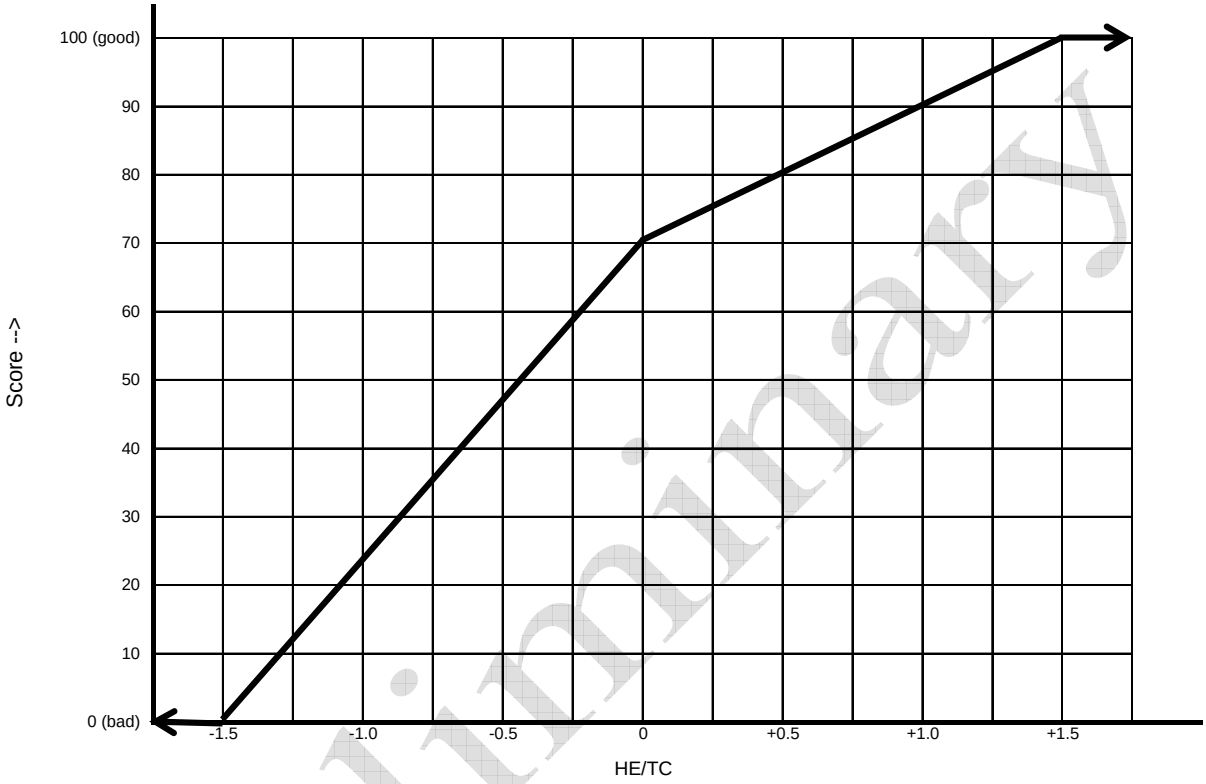
6.1.7 A value tree embodies a set of criteria. The next element needed is the scoring rules whereby each alternative (each irrigation project in this example) is assigned a merit score under each criterion. These are usually of two kinds; quantitative ones and qualitative ones.

6.1.8 A quantitative scoring rule uses a numerical parameter describing each alternative under each criterion, and sets out, usually graphically, how the scores are derived

from the parameter values. The example in Figure 2 shows a rule using a simple parameter whose definition is explained underneath the diagram.

Figure 2: An Example of a Quantitative (Numerical) Scoring Rule

Scoring rule for: **SOCIAL: Housing**



HE = Housing Equivalents			
2 bedroom house	=	1	HE
4 bedroom house	=	1.5	HE
School	=	20	HE
Pump station	=	0	HE
Railway line	=	0	HE
Hospital	=	0	HE

TC = Total Cost of Intervention (US$m)

Note: Houses to be destroyed - negative
Houses to be developed / saved from destruction or abandonment - positive

6.1.9 The impact of a particular intervention (or project) on housing is expressed in terms of "housing equivalents" (HE), which provides a series of weighting factors to allow the derivation of a single number to represent a summation of a variety of building types. However, the value of HE is taken to represent the general impact on the existing population. In order to provide a basis for comparison of different interventions the derived value of HE is divided by the total cost of the intervention. The scoring rule allocates a value of 70 to any intervention that would not involve the destruction of any buildings (and thus the moving of any people). The scoring rule recognises that some types of intervention could make a positive contribution to the housing stock, either by sustaining a current situation (which would otherwise deteriorate) or by providing new houses. The steeper gradient for the negative HE

part of the graph recognises the undesirability of moving people out of existing houses.

6.1.10 This example shows how non-linear decision-maker preferences can be used in the model. The "reliance on imports" criterion (taken as the value of imports as a proportion of the cost of the intervention) in the above value tree would be expressed in a quantitative rule of this sort, but the lines would slope the other way, since an intervention that relies more on the use of local resources is preferred. Again there could be slope changes and cut-off values: there is no need for a rule to be linear. Non-linear rule curves can be smooth rather than made up of straight lines as in this example.

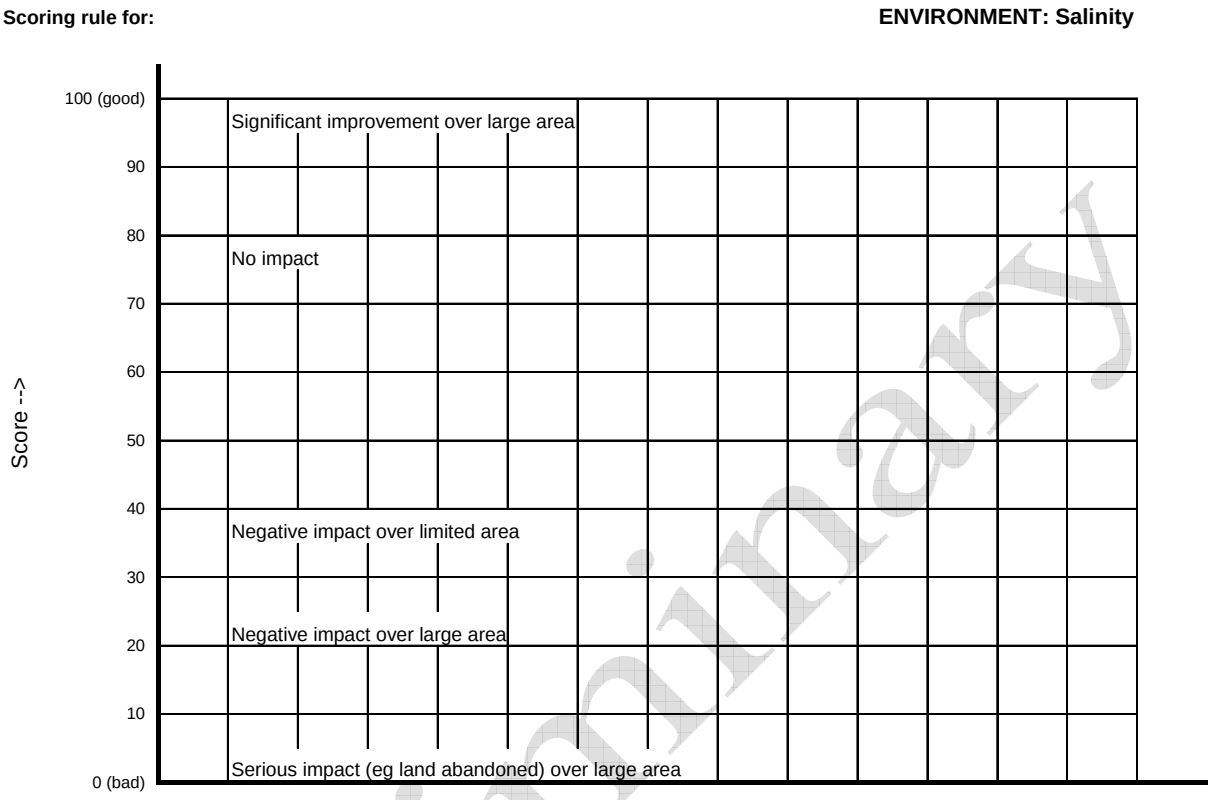
6.1.11 A qualitative scoring rule uses the same 0-to-100 merit scale, but the score is chosen subjectively for each alternative using the verbal markers as guidance. In the example in Figure 3 there is a neutral score, but this is not necessarily the case for all criteria. A rule like this can first be formulated in general terms, as here, and while it is being used more verbal markers can be written in at suitable scores to help people to remember how the scale has been used, and to score all alternatives consistently.

6.1.12 In this second example the score of zero can be used to indicate a veto, since a project that resulted in a serious impact over a large area, no matter how favourably it looked under other criteria, would be unacceptable. The model can also be operated without vetoes. Any individual criterion can be used just for ranking, or just for screening with a veto, or for both[9].

6.1.13 It is advisable, when setting the scores for the various alternatives, to keep a record of the reasoning behind the decisions, so that people can come back later and be reminded why a certain score was set. Simple standard forms are suitable. This is helpful when setting scores for a new set of alternatives at a later date. A set of such record sheets contributes to the definition of the scoring rule, forming an informative complement to the simple expression of the rule as shown here.

[9] The use of vetoes in effect applies a satisficing process. The sort of MCDM that operates entirely by satisficing, using threshold values, without scoring and weighting, has several disadvantages relative to the weighted-average model with vetoes. It is described in Section 4.4 of Belton & Stewart 2002.

Figure 3: An Example of a Qualitative (Verbal) Scoring Rule



6.1.14 The criterion weights should be set in discussion between a range of stakeholders or decision-makers, sometimes with the help of a facilitator. It is generally best to begin by agreeing which is the most important criterion and giving it an initial weight of 1, and then to discuss the weight to be given to the second most important criterion relative to that. The weight is not just people's intuitive idea of the importance of the criterion, but must be assessed by asking what interval on one criterion would be seen as a fair trade-off against a standard interval (such as the full range 0 to 100) on another criterion[10]. That is why the scoring rules should be developed and agreed before assessing the weights. Usually the weight of the most important criterion should not be more than 5 times that of the least important, since a greater ratio would give the least-weighted criterion very little influence on the overall merit index; an exception can be made when criteria with small weights have vetoes[11].

[10] This is called the 'swing weight method'; Belton & Stewart 2002, Section 5.4.2.

[11] Belton & Stewart 2002: Section 5.4.5: criterion weights should be checked by sensitivity tests on a few alternatives.

6.1.15 The final step in setting up a weighted-average model is the table, generally a spreadsheet, where the scores for each alternative are set out against each criterion, and the overall merit index is computed as the weighted mean. The example in Table 1 shows the criteria from the above value tree applied to an imaginary list of alternatives, using an imaginary set of weights and scores.

Table 1: An Example of a Table to Compute and Present the Results of the Model

A: ALTERNATIVES IN ORIGINAL LIST ORDER

Criterion group:	**economic merit**			**social impact**				**environmental impact**				**ease of quick implementation**				**multicriterion index for ranking**						**ranking without vetoes**	
group weight:	30%			30%				20%				20%				group contributions							
Criterion:	Cost	Cost / Benefit	Reliance on imports	Employ-ment	Housing	Land take	Cultural	Salinity	Other pollution	Animals and plants	Construct-ion impacts	Availability of suitable contractors	Current security situation	State of prepar-ation	Land available for implement ation	economic merit	social impact	environ-mental impact	ease of quick imple-mentation	**overall merit index**	**rank or veto**	index	rank
criterion weight:	5%	20%	5%	7%	10%	8%	5%	10%	3%	3%	4%	8%	4%	4%	4%	max 30	max 30	max 20	max 20	100			
Alternatives:	(relative merit scores under each criterion are from 1 to 100: a score of zero means a veto)																						
project A	70	65	50	35	50	60	40	50	80	80	30	100	70	100	100	19.0	14.3	11.0	18.8	63.1	2	63.1	3
project B	70	40	30	50	70	30	50	30	50	0	20	100	80	100	100	13.0	15.4	0.0	19.2	0.0	vetoed	52.9	7
project C	50	55	90	50	50	50	50	70	90	50	50	100	40	60	100	18.0	15.0	13.2	16.0	62.2	3	62.2	4
project D	95	80	50	55	50	55	60	50	25	60	35	50	70	100	20	23.3	16.3	9.0	11.6	60.1	4	60.1	5
project E	20	35	60	25	85	70	45	20	70	35	50	50	50	100	100	11.0	18.1	7.2	14.0	50.3	6	50.3	9
project F	85	60	45	50	90	30	35	40	45	75	50	100	70	0	100	18.5	16.7	9.6	0.0	0.0	vetoed	59.6	6
project G	75	50	15	80	70	70	100	60	50	90	70	100	70	100	100	14.5	23.2	13.0	18.8	69.5	1	69.5	1
project H	80	90	80	70	60	50	80	50	75	30	55	0	50	100	100	26.0	18.9	10.4	0.0	0.0	vetoed	65.3	2
project I	75	25	70	15	20	65	70	60	25	50	85	50	70	100	100	12.3	11.8	11.7	14.8	50.5	5	50.5	8

B: ALTERNATIVES IN RANKED ORDER

Criterion group:	**economic merit**			**social impact**				**environmental impact**				**ease of quick implementation**				**multicriterion index for ranking**						**ranking without vetoes**	
group weight:	30%			30%				20%				20%				group contributions							
Criterion:	Cost	Cost / Benefit	Reliance on imports	Employ-ment	Housing	Land take	Cultural	Salinity	Other pollution	Animals and plants	Construct-ion impacts	Availability of suitable contractors	Current security situation	State of prepar-ation	Land available for implement ation	economic merit	social impact	environ-mental impact	ease of quick imple-mentation	**overall merit index**	**rank or veto**	index	rank
criterion weight:	5%	20%	5%	7%	10%	8%	5%	10%	3%	3%	4%	8%	4%	4%	4%	max 30	max 30	max 20	max 20	100			
Alternatives:	(relative merit scores under each criterion are from 1 to 100: a score of zero means a veto)																						
project G	75	50	15	80	70	70	100	60	50	90	70	100	70	100	100	14.5	23.2	13.0	18.8	69.5	1	69.5	1
project A	70	65	50	35	50	60	40	50	80	80	30	100	70	100	100	19.0	14.3	11.0	18.8	63.1	2	63.1	3
project C	50	55	90	50	50	50	50	70	90	50	50	100	40	60	100	18.0	15.0	13.2	16.0	62.2	3	62.2	4
project D	95	80	50	55	50	55	60	50	25	60	35	50	70	100	20	23.3	16.3	9.0	11.6	60.1	4	60.1	5
project I	75	25	70	15	20	65	70	60	25	50	85	50	70	100	100	12.3	11.8	11.7	14.8	50.5	5	50.5	8
project E	20	35	60	25	85	70	45	20	70	35	50	50	50	100	100	11.0	18.1	7.2	14.0	50.3	6	50.3	9
project B	70	40	30	50	70	30	50	30	50	0	20	100	80	100	100	13.0	15.4	0.0	19.2	0.0	vetoed	52.9	7
project F	85	60	45	50	90	30	35	40	45	75	50	100	70	0	100	18.5	16.7	9.6	0.0	0.0	vetoed	59.6	6
project H	80	90	80	70	60	50	80	50	75	30	55	0	50	100	100	26.0	18.9	10.4	0.0	0.0	vetoed	65.3	2

6.1.16 If there is a hierarchy of criteria, as in the example value tree in Figure 1, it is usefully informative to show also the index contributions from the different groups, so that one can use the table to see and explain why one alternative outranks another. For instance, it may do so because of high scores in the environmental and quick-implementation groups, despite a relatively low economic score.

6.1.17 In the upper part of Table 1 the index values and ranks have been computed, but the alternatives are still in their original list order. The lower part shows the same results but with the alternatives sorted into rank order, which is more convenient for some purposes. The overall merit index values give more information on the outcome than the ranks do. It can be seen that the best project, G, is preferred by a considerable margin over the next-best one, project A, while the margins separating projects A, C and D are smaller. The margin between project D and the next worst one, I, is very wide.

6.1.18 Study of the group contributions show that project G was preferred above projects A, C, and D because of its high rating in the social and environmental groups, despite having lower economic merit that any of those. A sensitivity test shows that it would have needed a large shift of weight away from social and environmental criteria, towards economic ones, to reverse that preference.

6.1.19 The table also shows the operation of vetoes. Project B was vetoed because of some very severe impact on ecosystems, project F was vetoed because its tender documents were not ready, and project H because there was considered to be no chance of attracting a competent contractor. So long as these vetoes stand, these projects cannot be selected for funding. But it is useful to know which of them is most worth looking at to see if it can be modified and the veto can be lifted, if not immediately then in time for next year's allocation round (the iterative allocation process is described further in the next section). The two extra columns on the right of the table help with this. They show what the index values and ranks would have been in the absence of the vetoes. Project H would have been ranked second, mainly because it has the highest economic merit in the whole list. This indicates that it would be worth while to make a big effort to overcome the problem about contractors for that one. Project F, without its veto, would still only have been ranked sixth (or fifth if H were still vetoed), so there would probably not be much point in making a big effort to finish its tender documents in time for the current year. Project B would have been ranked very low even without its environmental veto, and a quick sensitivity test shows that even if its ecosystems score were neutral, about 50, it would still rank seventh. So it would be difficult to make a case for spending a lot of effort to redesign it quickly to avoid the ecological impact.

6.1.20 This discussion illustrates how a transparent model of this kind can yield a great deal of useful information quite easily, and can facilitate discussion among decision-makers, with or without help from their facilitators. Once the model is set up and the ranking is computed with the chosen scoring rules and criterion weights, is it advisable to conduct a number of sensitivity tests with the decision-makers, leading

to discussion and probably some adjustment to scores or weights until the working of the model is judged to be a fair representation of the consensus judgements of the relevant parties. A sensitivity test on a single score or weight takes only a few seconds and the change can be projected on a screen, undoing and redoing it to watch what difference it makes. A change to a scoring rule takes longer because all the candidate alternatives have to be scored again.

6.1.21 There will probably be arguments and disagreements at this stage, especially the first time a new model is used, but this is better than merely arguing about a list of alternatives without any such structure.

6.1.22 A weighted-average model as described here can handle quite complex problems, for instance up to twenty or more criteria and hundreds of alternatives if needed, without losing its essential simplicity and transparency. The examples given here are only illustrations.

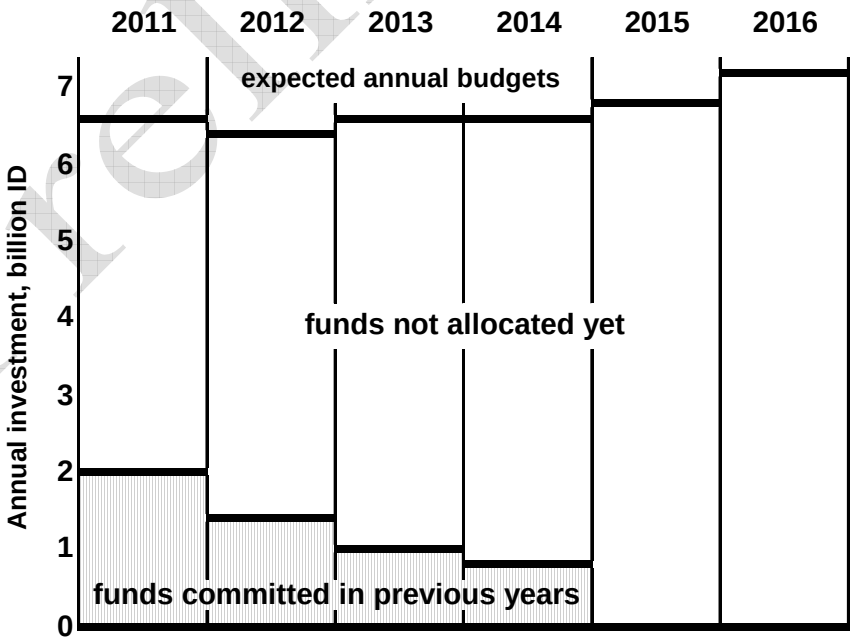
7 How the Model Can Be Used for Prioritising Investments

7.1.1 A model of this sort is sometimes used just to select one preferred alternative among many ways of achieving a single purpose. But this Guidance Note and the above imaginary example, concern its use for prioritising alternative investments that are competing for a limited budget. This section describes how such resource allocation can be done.

7.1.2 The model is intended to be used as part of a routine annual cycle of fund allocation, alongside a policy of commitment funding. (This means that once a multi-year alternative, project or contract has been started in a particular year, the funds for all its years are fully committed.) The starting-point is

- a model, at least tentatively agreed among the decision-makers;
- a list of alternatives, all being candidates to start in the next year, with their scores;
- a set of budget ceilings for the next few years, noting any funds already committed by earlier decisions so as to determine the remaining 'budgetary room' for each future year (as illustrated).

Figure 4: Estimated budgetary room for the next six years



7.1.3 The normal steps of the process then are:

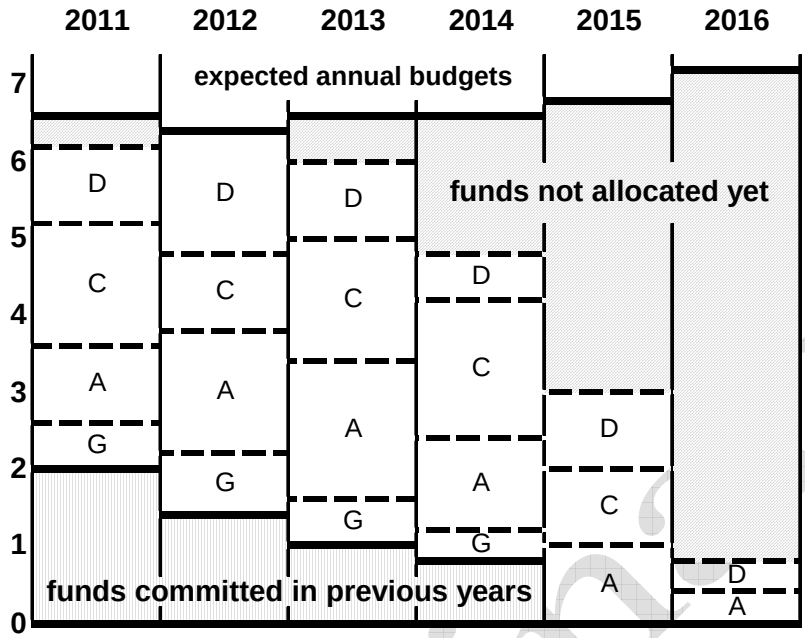
1. The model is computed with the full list of alternatives, and when it has ranked them they are sorted into rank order as shown in the lower part of Table 1 above.

2. The analysts and decision-makers review all the features of the model, especially its scoring rules and weights. Although they resulted from a consensus earlier, the decision makers may reasonably wish, after seeing what priorities they result in, to adjust them a little. Adjusting weights, or individual scores of particular alternatives, is quick to do and the results can be displayed during a meeting and discussed. As mentioned above, changing a scoring rule takes much longer, since all alternatives have to be re-scored with the new version of the rule, and criterion weights may have to be reconsidered in the light of the new scale; such model changes would have to be done by the analysts separately and presented to a later meeting of the decision-makers. This iterative process can take some time, especially in the first year that a new sort of model is used, but after a few years the model should settle, and people should become more adept at managing it, so the iterative process should get quicker and easier.

3. The analysts and the decision-makers then begin the allocation of funds by provisionally allocating funds to the highest ranked alternative (ignoring vetoed ones), provided there is room in the future budgets for all its years of implementation.

4. This is repeated for the next highest alternative, remembering that some of the 'budgetary room' has already been committed to the higher one, and so on until the budget ceiling of one of the future years is reached. (This is illustrated here for the imaginary example, assuming that the second year's budget is full after four projects have been inserted.)

Figure 5: Position after provisional allocations to four projects



5. If that ceiling has been reached because of a particularly large requirement by one alternative in one year (project D's second-year requirement in the illustration), the remaining list of alternatives is inspected to see if, by dropping one of the projects already selected, some slightly lower ranking alternative can be inserted to give a better overall fit to the whole set of budget ceilings. This involves some compromise, since a lower-ranked alternative will be included and a higher-ranked one omitted, but if there seems to be good reason to do this a consensus may be reached; the omitted one will stand a good chance of being funded next year, especially if its year-by-year investment schedule can be smoothed or spread to make it fit in better (it might even be rescheduled straight away and resubmitted for selection, perhaps getting back into the current allocation batch). It is generally better that the first year of the planning period should be filled first, not the second as illustrated here, since this will leave a more convenient budgetary room for next year's allocation process.

6. Either after or alongside that adjustment process, the provisional investment list for the next year is inspected to see if the balance of alternatives between regions or provinces is reasonable. This can involve a number of pragmatic, social or political criteria such as the desire to keep a reasonable flow of work in each region, or to promote development in a particular region faster than the merits of its alternatives would normally justify. Because they concern the volume of investment in a region (or perhaps in a category of alternatives), rather than the separate merits of single alternatives, these criteria have to be applied at this stage, not inside the prioritising model. The process should be transparent, and once agreement has been reached on some compromise the reasons for it should be recorded, before people move on to something else and begin to forget them.

7. At the conclusion of this process there will be an agreed investment programme for the first year of the plan period (normally the year following the meetings), a new set of commitments for subsequent years, and a record of the reasons for all the scoring, weighting and allocation decisions.

8. During the implementation of the investments in the following year, some small re-allocations may be desirable, if some projects spend funds a little faster or slower that was planned, but this should be done in a disciplined way, for instance using small contingency allowances within the project budgets.

9. All remaining alternatives, including vetoed ones, can stay on the candidate list for possible selection in the next year's allocation round, unless some are seen to have so little merit that they should be abandoned altogether.

10. Now attention can turn to the alternatives that were not selected. This is where the last two columns of the example in Table 1 become useful. The index values and without-veto ranks show which alternatives are most worthy of attention in preparation for next year's allocation round. In particular they show which of the vetoed alternatives might be worth-while if a way can be found to avoid their vetoes next time. In the case of pragmatic vetoes like those relating to lack of tender drawings this may be quite easy to do within in a few months, and if there are many such vetoed alternatives the ranking will indicate which ones to attend to first. There may be some other alternatives which, although not vetoed, achieved low ranks but, with guidance from their scores and ranking, can be improved in time for the next round. So this veto-free ranking helps to guide the allocation of study and preparation effort in the run-up to the next year's allocation process.

7.1.4 Like the preparation of the model, this process for its use must be transparent, and the reasons for all decisions should be recorded. Some of the above steps give considerable opportunity for subjective, political or even irrational motives to be applied. Some political, region-specific or project-specific reasoning may be fully justifiable, and the point here is that a transparent process ensures that it does need to be explicitly justified and recorded. This should help to maintain efficient allocation of resources, in the broad national interest.

8 International Experience with MCDA

8.1.1 Systematic multi-criterion models have been used to guide decisions of many sorts in many countries over the last few decades. There is an extensive literature on the subject, and some very sophisticated mathematical techniques are constantly under discussion among academics and practitioners[12]. The Consultant has experience of using the simple weighted-average model to prioritise investments for water quality improvement projects in China, and for selecting project type and location in UK, while on another occasion (water pollution control) a different sort of model was chosen because of the nature of the problem. The literature contains references to models in use for national master planning in Norway and for Canada's hydropower and defence sectors[13].

[12] The literature up to about 2001 is well reviewed and referenced in Belton & Stewart 2002, Professor Belton having been the editor of the relevant journal for some years while Professor Stewart is now the president of the International Society on Multiple Criteria Decision Making. Current debate can be seen in the abstracts of the association's 2006 conference (ISMCDM 2006).

[13] WCD 2000, page 74; ISMCDM 2006, page 88.

9 References

Belton & Stewart 2002 — *Multiple Criteria Decision Analysis, an integrated approach*; V Belton & T J Stewart, Kluwer Academic Publishers, 2002 (ISBN 0-7923-7505-X)

ISMCDM 2006 — *18th International Conference on Multiple Criteria Decision Making, 19-23 June 2006: book of abstracts*; International Society on Multiple Criteria Decision Making; 2006. [www.dpem.tuc.gr/fel/mcdm2006]

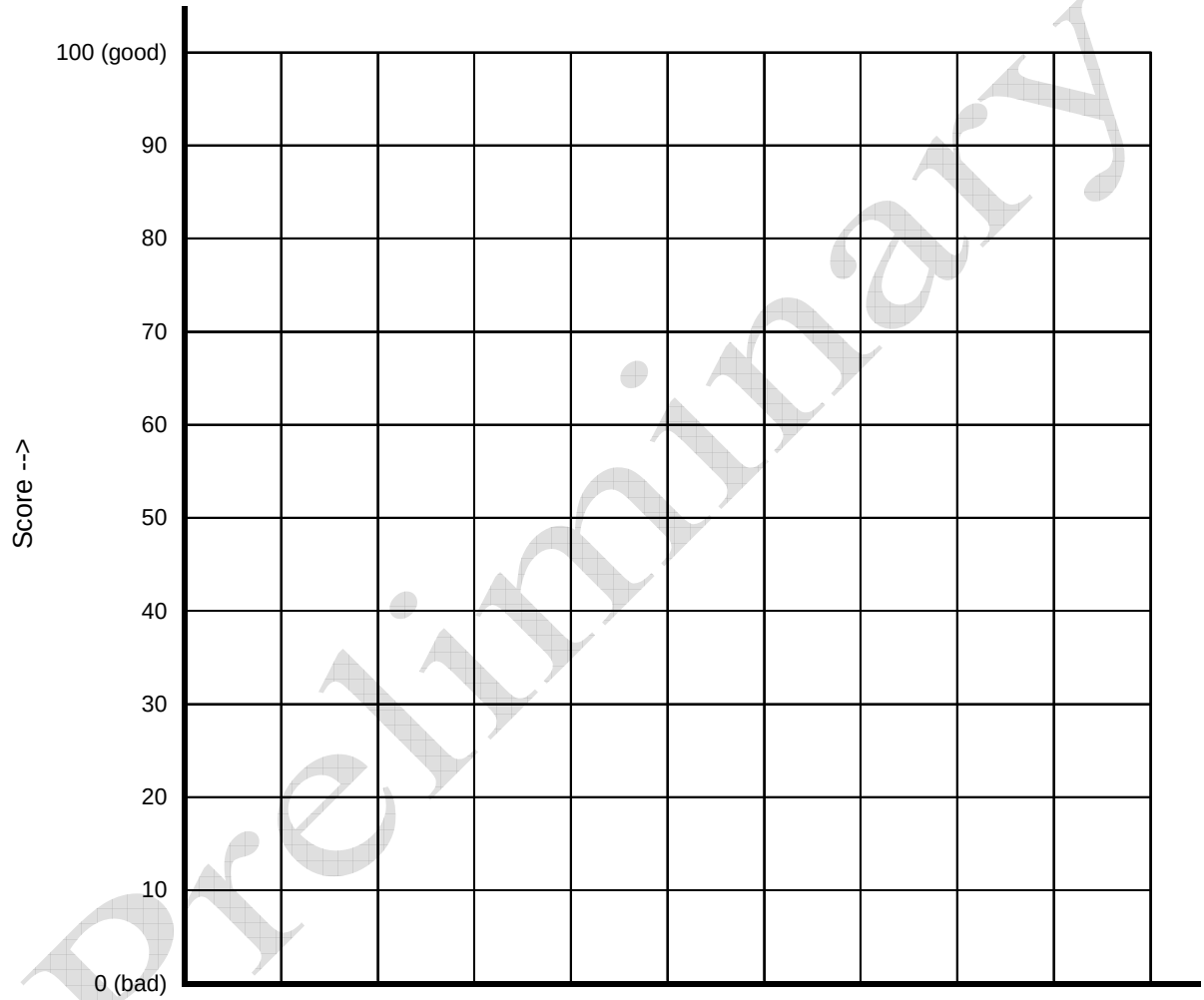
Snell 1997 — Appendix F of *Cost-benefit analysis for engineers and planners*; M J Snell; Thomas Telford, 1997 (ISBN 0 7277 2587 4).

WCD 2000 — Section 4 of *Planning Approaches; Thematic Review V.1;* prepared as an input to the World Commission on Dams by D Nichols, D Von Hippel & T Stewart; Cape Town, November 2000. [http://www.dams.org/kbase/thematic/tr51.htm]

Appendix A Forms

A.1 Form for drafting scoring rules

Multi-criterion Decision Model
scoring rule for:



A.2 Form for recording scores and the reasoning behind the choice of score

PROJECT: ----------

CRITERION (Second Level): ----------

CRITERION 1 (Third Level): ---------- SCORE: ☐ %

COMMENTS:

STUDY NEEDED? ☐ Y/N	DETAIL:

CRITERION 2 (Third Level): ---------- SCORE: ☐ %

COMMENTS:

STUDY NEEDED? ☐ Y/N	DETAIL: