# CARBOWASTE

*Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste*

**Grant Agreement Number: FP7-211333**

## Deliverable (D-1.4.2)

## - Selection of Appropriate MCDA Tool/Methodology -


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| **Selection of Appropriate MCDA Tool/Methodology** |
| Executive summary |

This report reviews the most common MCDA approaches/tools and identifies the most appropriate for the CARBOWASTE project by evaluating these against the highest-level objectives of the project. This first draft of the report outlines the selection process and the next steps in terms of implementation.

A set of criteria by which options will be assessed is proposed. There will be particular challenges in terms of alignment with the MCDA criteria being developed within other work packages, in particular WP2 (Retrieval and Segregation), WP4 (Treatment and Purification) and WP6 (Disposal Behaviour). The criteria outlined in this document should therefore be seen as an indicative list which will be developed and customised further under subsequent related WP1 tasks.

There are several past, and current, european-level projects which have carried out wide-ranging MCDA reviews. These include projects concerning radioactive waste management. This current review aims to learn from, and build upon, this previous experience.

Three MCDA methods have been found to be suitable for deployment on the CARBOWASTE project. Each have their strengths and weaknesses, which are discussed in this document.

An initial evaluation of supporting software packages has been carried out and is reported on.

The principal conclusions of this report are as follows:

- No single MCDA technique out-performs the others;
- Three of the leading MCDA methods (MAUT (including SMART and Linear Additive), AHP and OUTRANKING) are suitable for deployment in the MCDA tool box and will be carried forward into the next phase of support software evaluation;
- Several previous (and current) EU projects have studied MCDA in depth, providing ‘benchmarks’ for the CARBOWASTE project;
- A top level set of criteria suitable for use in the CARBOWASTE project has been proposed; and
- Software systems are available to support the methods; some of the simpler methods require minimal programming.

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|---|---|---|---|---|---|---|
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# 1 Introduction

A form of multi-criteria analysis (MCA) that has found many applications in both public and private sector organisations is multi-criteria decision analysis, or MCDA for short (also known as multi-attribute decision analysis, or MADA).

MCDA is both an approach and a set of techniques, with the goal of providing an overall ordering of options, from the most preferred to the least preferred option. The options may differ in the extent to which they achieve several objectives, and no one option may be obviously best in achieving all objectives. In addition, some conflict or trade-off is usually evident amongst the objectives; options that are more beneficial are also usually more costly, for example. Costs and benefits typically conflict, but so can short-term benefits compared to long-term ones, and risks may be greater for the otherwise more beneficial options.

MCDA is a way of looking at complex problems that are addressed by options characterised by any mixture of monetary and non-monetary objectives. MCDA facilitates breaking the problem into more manageable pieces to allow data and judgements to be brought to bear on the pieces, and then reassembling the pieces to present a coherent overall picture to decision makers. The purpose is to serve as an aid to thinking and decision making, but not to take the decision. As a set of techniques, MCDA provides different ways of disaggregating a complex problem, of measuring the extent to which options achieve objectives, of weighting the importance of each of the objectives, and of reassembling the pieces.

This report summarises the process for, and results of, a review[1] (Task 1.4.1) of various MCDA tools/methodologies previously employed for relevance to the project. It: -

- Underpins the strategy for orientation and control of the CARBOWASTE project ;
- Takes account of feedback raised at the WP1/WP2 workshop in Manchester, UK on 16-18 February 2009 ; and
- Contributes toward the establishing of an MCDA compartment of the CARBOWASTE tool box.

The report establishes the framework for development of the MCDA processes in the CARBOWASTE project so that these can be deployed effectively during 2010/11.

The activities to derive and implement the MCDA tools/methodologies for the CARBOWASTE tool box for legacy i-graphite wastes are outlined in the CARBOWASTE, Grant Agreement No. 211333, Annex I – "Description of Work" Version U[2]. Section B1.3.5 describes the activities relevant to the following tasks:

- Task 1.4, Review MCDA techniques, resulting in a review report of the various MCDA tools/methodologies previously employed for relevance to this project, and this report ;
- Task 1.5, Undertake Multi-Criteria Decision Analysis (MCDA) at key stages of the road map, resulting in reports of the results of the MCDA analyses and the high- and low-level objectives and criteria used in the assessments;

- Task 1.6, Retrieval Criteria, which results in a report of the assessment of the retrieval options against the relevant criteria; and
- Task 1.7, Synthesis, which results in a report which will enable readers to easily appreciate and use the methodology to derive their appropriate options.

These tasks are underpinned by Tasks 1.1, 1.2 and 1.3 which respectively deliver reports which:
- Review existing strategies and technologies for waste management of i-carbonaceous materials;
- Address end points for each key stage of the in-reactor storage to disposal route; and
- Identify gaps in knowledge base that impact on the above two tasks.

The present issue of this report is draft for comment and any comments on it should be sent to David Ross, National Nuclear Laboratory by 30th May 2009. A presentation of the key findings of this MCDA review[3] was presented to WP1 and WP2 beneficiaries at the meeting at Manchester Conference Centre on 18th February 2009.

# 2 Objectives

The stated overall CARBOWASTE project objective[2] is:

*"The development of best practices in the retrieval, treatment and disposal of irradiated graphite (i-graphite) including other carbonaceous waste like structural material made of graphite or non-graphitised carbon bricks and fuel coatings (pyrocarbon, silicon carbide)."*

In this context, the WP1 task leaders (the National Nuclear Laboratory (NNL)) are charged with delivering the following tasks:

*"An integrated waste management road map for i-graphite will require end points at key stages of the road map to be evaluated against specific criteria."*

*"…the various MCDA approaches/tools will be reviewed and the most appropriate selected balanced against the highest-level objectives of the (CARBOWASTE) project."*

*"Key criteria will be identified such as cost, safety and subsequently lower-level objectives and finally performance criteria."*

*"Judgements will be based on economic, safety, environmental and socio-political impacts, taking account of member states considerations."*

*"Technology evaluation will have to address eco-engineering considerations such as:*

- *Engineering: development from conceptual via laboratory to commercial stage;*
- *Versatility: accommodating various feed sources;*
- *Flexibility: changes in process conditions have little influence on product quality;*

- *Simplicity: requires minimal operative involvement or readiness for automation;*
- *Robustness: product quality, safety & environmental discharges vs. mal-operations;*

- *Efficiency: use of feed stocks to products with the minimum of re-work and effluents;*
- *Predictability: process can be easily configured and modelled;*
- *Compactness: small foot print area, potential for modularity;*
- *Product quality: coping with the customer/market specification;*
- *Environmental impact: energy needs, abundant/low cost & non toxic materials usage;*
- *Secondary wastes: small but readily treatable, recycle/dispose off with relative ease."*

This then enables:

*"….Multi-Criteria Decision Analysis (MCDA) at key stages of the road map."*

WP1 represents the 'Strategic Optioneering' for the whole project and so must identify the economic, ecological and licensing requirements for i-graphite waste management. The selection of retrieval, treatment and disposal options will have to be guided by Member State targets (end points).

The approach proposed by this work package, combined with information drawn from the other five work packages, will then allow:

- Selection of retrieval, treatment, storage and disposal processes;
- Multiple criteria comparisons of a base case option (such as disposal of all retrieved materials as encapsulated waste), to other options developed in this project; and
- Sensitivity analysis of project decisions to changes in input data.

The output from Tasks 1.1 – 1.4 is an MCDA tool box 'compartment' containing the MCDA methods and associated software, high level and low level assessment criteria and associated guidance on use of the methodology. Depending on the outcome of further studies, it is likely that an internet-based IT 'platform' will also need to be established to facilitate easy access to the techniques and associated data.

The aim of this report is to summarise the findings of a CARBOWASTE MCDA Literature Survey[1], and to determine the most suitable MCDA technique(s) for use in the CARBOWASTE project.

# 3 Methodology and Results

This section discusses the approach adopted for, and results of:

- A review of the MCDA approaches/tools;
- Selection of the recommended technique(s);
- Identification of the low and high-level assessment criteria;
- Identification of software support needs; and
- Identification of high-level assumptions/constraints

## 3.1 Review of MCDA approaches/tools

### 3.1.1 Methodology

There are a very large number of MCDA tools and techniques reported in the literature. The review[1] presented in was kept to a manageable size by drawing heavily on a number of previous reviews of decision-making tools and techniques and associated case studies. Several of these had been carried out at national and european levels. These reviews and case studies, particularly those at the EU level, provide a good benchmark for the CARBOWASTE project in terms of identification of suitable techniques. Recent EU projects which evaluated MCDA techniques include the following examples:

- Strategic Environmental Assessment – Building Environmental Consensus (BEACON)
- Contaminated Land Rehabilitation Network for Environmental Technologies (CLARINET)
- Co-operative research on the Governance of Radioactive Waste Management (COWAM)
- Multi-criteria Software Decision Analysis Tool for Renewable Energy Sources (MCDA-RES)

These reviews, in particular MCDA-RES, provide a ‘benchmark’ for provision of an MCDA tool box within the CARBOWASTE project.

To ensure that a comprehensive review of MCDA techniques was undertaken and that there was a good understanding of the various methods, the literature survey[1] included brief consideration of the theoretical foundations of the various approaches. The different MCDA approaches all follow the same basic approach outlined in Appendix 1.

The field of multi-criteria analysis is very broad and there are a number of techniques which, whilst not strictly falling into the MCDA category, are nonetheless frequently encountered in practice in decision making contexts. These related techniques were also considered[1] in to ensure their relationship to MCDA techniques was well understood.

### 3.1.2 Results

The results of the MCDA Literature Survey have been reported[1]. The findings may be summarised as follows:

- There are many thousands of MCDA-related studies and reviews in the literature;
- There is no consensus favouring one particular method, each of the most common approaches have their pros and cons;
- The leading methods are based on techniques for Optimisation and/or Outranking/ Dominance;
- Methodologies are generally based on either multi-option or pair-wise comparison techniques;
- Several techniques can allow for uncertainty in data; and
- The leading methods are supported by a range of software applications

## 3.2 Selection of technique(s)

### 3.2.1 Methodology

Guidance on selection of MCDA techniques is available in the UK Government MCA Manual[4]; this approach has been adopted here as it was found to cover all of the key generic selection criteria, namely:

A. Internal consistency and logical soundness;
B. Transparency (weights and scoring);
C. Ease of use;
D. Data requirements not inconsistent with the importance of the issue being considered;
E. Realistic time and manpower resource requirements for the analysis process;
F. Ability to provide audit trail; and
G. Software available where needed.

Each of the techniques was evaluated against these generic criteria. A second stage of evaluation against the more specific requirements of the CARBOWASTE project at the respective road map stages will develop as the number of options, and criteria, become more precisely defined. A further consideration will be the context for the application of the MCDA technique as this introduces additional variables which may be site, region or country-specific. An indicative list of implementation considerations is included in Appendix 2.

### 3.2.2 Results

The specific requirements of the CARBOWASTE project in relation to MCDA technique selection are not known at this project stage. It is expected that there will be a large number of criteria requiring consideration at each of the project stages (Retrievals, Storage, Treatment and Disposal).

The precise number of options under consideration at each stage is also unclear, but is likely to be low (< 5) or even very low (1 or 2) for some of the road map end-points. Each of the candidate techniques is judged, in principle, to be suitable for application at any of the project stages.

The MCDA methods which were described in detail and reviewed in the literature survey[1] included:

1. Multi-attribute Utility Theory (MAUT)
2. Simple Multi-attribute rating technique (SMART)
3. Analytical Hierarchy Process (AHP)
4. Outranking
5. Linear Additive
6. Ideal Point
7. Non-compensatory methods

Methods 1-5 are selected on the basis of meeting the criteria A-G above. Method 6 is de-selected as it is not in widespread use. The group of methods referred to as ‘non-compensatory’ whilst not selected for further consideration under the main MCDA study are nonetheless identified as being useful for initial coarse screening of options. Techniques which use more input data to incorporate uncertainty in scoring and weighting such as the 'evidential reasoning' technique have previously[1] been discussed and evaluated. However, such methods are not considered further as it is not believed that the CARBOWASTE project will require this level of sophistication to discriminate between options.

A key differentiator between methods 1-5 will be in the support software requirements (in terms of complexity); this varies from low (Linear Additive/SMART) to medium (MAUT) and high (AHP/Outranking). Detailed software requirements will be the focus of the next phase of this study.

The detailed evaluation findings are presented in Appendix 3.

A more detailed description and comparison of methods 1-5 is to be found in Appendix 5.

## 3.3 Identification of high and low-level assessment criteria

### 3.3.1 Methodology

It is important that a generic set of MCDA criteria are agreed for the project at the outset, from which tool box users can derive a set of evaluation criteria relevant for their decision context. This then enables users to focus on the relevant criteria whilst being in a position to justify why other criteria from the complete set have been excluded. In the course of the literature survey[1], a wide range of criteria lists were encountered. Nonetheless, generic high-level criteria can be readily identified. Derivation of lower level criteria (it is anticipated that 3 or possibly 4 levels of criteria may be needed, depending on the context) will be the subject of the next phase of work in WP1.

### 3.3.2 Results

#### *3.3.2.1 High-level Assessment Criteria*

These are relatively straightforward to determine as they need to be sufficiently generic to ensure comprehensive coverage of all potential considerations:

1. Risk to Health and Safety
2. Security of Hazardous Materials
3. Environmental Risk
4. Economic Impact
5. Cost
6. Stakeholder Acceptance
7. Technology/Methodology Performance

Criteria 2 and 7 are incorporated to reflect respectively the importance of the radioactive materials under consideration, and to acknowledge the scale of the technology challenge which the project presents.

These are believed to fully reflect the range of criteria (*economic, safety, environmental and socio-political impacts)* required by the task specification.

#### 3.3.2.2 Low-level Assessment Criteria

These are presented in Appendix 4. These have been developed into an indicative second tier of criteria. As previously mentioned, it may be necessary to define several further levels of criteria. Further development of, and agreement to, these criteria is the subject of the related task 1.5.1. It is anticipated that there will be significant differences in lower-level criteria for the different project stages (retrieval, treatment and disposal).

## 3.4 Identification of software support needs

### 3.4.1 Methodology

A conscious decision was taken to evaluate the MCDA approaches first and then progress to consideration of software systems. There are numerous software systems available, with some packages available in several different variants. Several of the references considered in the literature survey[1] included sections on evaluation of software systems and this has provided an early indication of the availability, and cost, of such systems.

### 3.4.2 Results

The candidate MCDA techniques are supported by numerous proprietary software systems, including:

| MCDA Method | Software |
|---|---|
| MAUT/ SMART/LINEAR ADDITIVE | HIPRE3+, SIMPLE SPREADSHEET TOOLS |
| AHP | HIPRE3+, EXPERT CHOICE, HIVIEW (MACBETH) |
| OUTRANKING | ELECTRE and PROMETHEE |

These packages will be evaluated in the next phase of the project against the CARBOWASTE project MCDA requirements. Availability of packages is not anticipated to be an issue; in addition to those listed in the table, there are a wide range of further alternatives available.

Brief details of these systems is included in the 'Definitions' section below.

## 3.5 Identification of high-level assumptions/constraints

### 3.5.1 Methodology

The U.S. Department of Energy Guidebook to Decision Methods[5] provides guidance on methods on determining the 'must do' requirements of MCDA projects has been consulted regarding the derivation of assumptions/constraints. These requirements are strongly context dependent but it is nonetheless possible to determine high level categories for these from which lower-level assumptions and constraints can subsequently be derived.

The Guidebook indicates that the essential task in this step is to segregate the requirements from the goals. Requirements are used to screen inadequate alternatives from further evaluation. The true test is to ask the question, "If an otherwise good alternative does not meet this requirement, should it be dismissed or considered?" If the answer is to dismiss the alternative, this is truly a requirement.

### 3.5.2 Results

Generic essential requirements for the CARBOWASTE project are as follows:

- Reduces the volume of i-graphite which has no disposal solution;
- Can be delivered within the decommissioning organisation resource constraints (principally costs); and
- Delivers compliance with relevant laws and policy (assumed to encompass all health, safety, security and environmental requirements)

It is noted that availability of a technical solution to the retrieval/storage/treatment/disposal challenge is only an essential requirement if the solution has to be deployed *immediately*. In all other cases it would not be an absolute requirement because it may be possible to develop a solution in the period between reactor shutdown and the programmed graphite retrieval/ storage/treatment/disposal date. It is of course an objective of the CARBOWASTE project to investigate the feasibility of novel technical solutions where none currently exist.

# 4 Conclusions

The following conclusions may be drawn from the CARBOWASTE MCDA study:

- No single MCDA technique out-performs the others;
- Three of the leading MCDA methods (MAUT (including SMART and Linear Additive), AHP and OUTRANKING) are suitable for deployment in the MCDA tool box and will be carried forward into the next phase of support software evaluation;
- Several previous (and current) EU projects have studied MCDA in depth, providing 'benchmarks' for the CARBOWASTE project;
- A top level set of criteria suitable for use in the CARBOWASTE project has been proposed; and
- Software systems are available to support the methods; some of the simpler methods require minimal programming.

# 5 Definitions

## 5.1 Software Systems

ELECTRE

ELECTRE is a family of MCDA methods. ELECTRE stands for: ELimination Et Choix Traduisant la REalité (ELimination and Choice Expressing REality).

The ELECTRE method can be applied to option selection, ranking and sorting. The method evolved into ELECTRE I (*electre one*) and the evolutions have continued with ELECTRE II, ELECTRE III, ELECTRE IV, ELECTRE IS and ELECTRE TRI (*electre tree*).

It is usually classified as an "outranking method" of decision making.

The ELECTRE series of MCDA software packages are available from the University of Paris-Dauphine, France.

EXPERT CHOICE

Expert Choice is a software package, developed by Expert Choice Inc. in the USA, which supports the application of the AHP to decision problems. There are a number of different configurations of the Expert Choice software. The basic software, Expert Choice for Individuals is a single user product and allows entry of consensus judgements during the pair-wise comparison and ratings assessment processes. The Group versions of the software allow individual decision makers ('participants' in Expert Choice terminology) to record their own judgements. These can be used as a platform for discussion before entering a consensus or they can be mathematically aggregated to provide a 'combined' set of judgements. The different configurations allow for different modes of entry of these individual judgements.

HIPRE 3+

HIPRE 3+ integrates the AHP and SMART techniques. These can be run independently or in combination. HIPRE 3+ is designed to be intuitive and used directly by the decision makers. HIPRE 3+ incorporates a customisable graphical interface. A free demo version of HIPRE 3+ is available from the Systems Analysis Laboratory of Helsinki University of Technology at www.hipre.hut.fi.

HIVIEW (MACBETH)

MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) is a multi-criteria analysis method that uses qualitative judgements about differences of value to help decision-maker(s) quantify the relative attractiveness of options. The approach, based on the additive value model, supports prioritisation and selection of options in an individual or group decision-making processes. MACBETH is a tool that converts a verbal descriptive scale into a numerical one for multi-criteria analysis. HIVIEW is a commercial software package available from Catalyze Ltd. (current cost £950) and is based on the MACBETH technique.

PROMETHEE

PROMETHEE is a widely used multi-criteria assessment algorithm. PROMETHEE I and II (Preference Ranking Organisation Method for Enrichment Evaluations) aggregate the information by an outranking procedure and finally rank the options. PROMETHEE I identifies incomparability between options. PROMETHEE II delivers a complete ranking of all options. A feature of PROMETHEE software (Decision Lab) is the use of stability intervals, which are intervals of weights for which the rankings remain unaffected. Decision Lab is commercial software and currently costs CA$ 1450; it is available from Visual Decision Inc. at www.visualdecision.com

# 6 References

Please note that these references have not yet been formatted.

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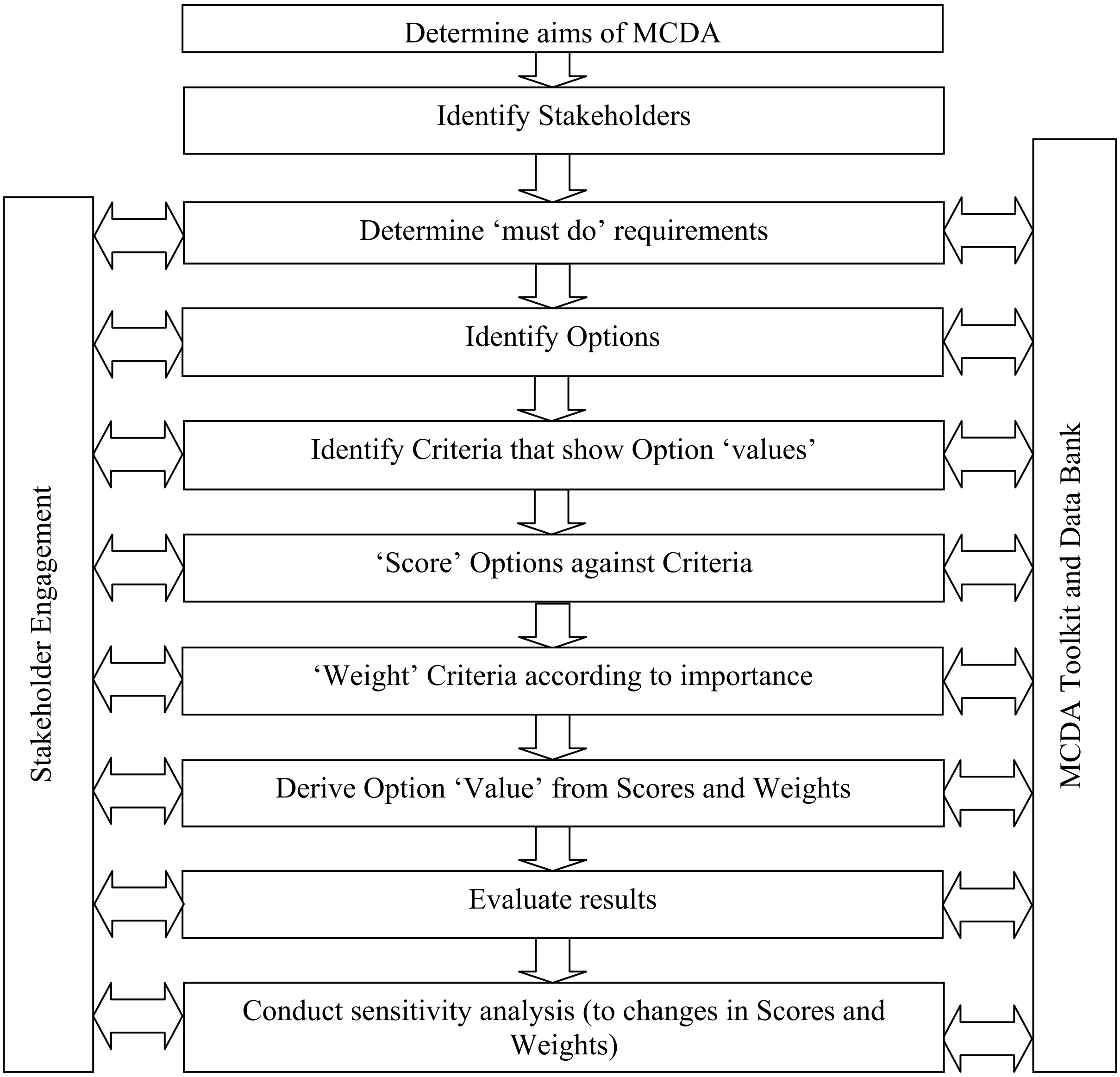
2. Carbowaste: Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste, February 2008, 7th Framework Euratom Nuclear Research and Training Activities, Grant Agreement 211333, Annex 1 Version U, European Commission
3. CARBOWASTE Project: Multi-Criteria Decision Analysis (MCDA); Presentation by D N Ross at the Carbowaste First WP1 Meeting, Manchester, UK, 17th February 2009
4. Multi-Criteria Analysis, Communities and Local Government, 28th January 2009, ISBN 9781409810230, available from communities.gov.uk
5. Baker D., Bridges D., Hunter R., Johnson G., Krupa J. Murphy J., Sorenson K., December 2001, Guidebook to Decision-Making Methods, U.S. Department of Energy, WRSC-IM-2002-00002

Appendix 1

Generic MCDA Process



Appendix 2

MCDA Implementation Considerations

1. Level of application – strategic or tactical.
2. Ease/difficulty of achieving reliability, consistency and clarity in weighting the criteria and scoring the options against the criteria:
    a. Numbers of options to be compared.
    b. Number of criteria.
    c. Quality and quantity of available data; whether qualitative or quantitative (or both).
    d. Independence of criteria.
    e. Dependence on a small number of data sets.
3. Ability to accommodate new options.
4. Whether options are to be compared in pairs, or as a group.

Appendix 3

Detailed Evaluation of Leading MCDA Techniques

MAUT/SMART/LINEAR ADDITIVE

| | | |
|---|---|---|
| A | Consistency/Logic | Attributes need to be independent, otherwise good. |
| B | Transparency | Weights and scores are easily understood but difficult to establish utility function (MAUT). |
| C | Ease of use | Requires facilitation and sensitivity analysis; simple techniques – experts not required to run process. |
| D | Data requirements | Scalable to complexity of problem. |
| E | Analysis requirements | Need to generate the information :<br>• person per attribute – with expertise (Health, Safety, Environment).<br>• sensitivity analysis: time consuming (use software).<br>• positive: considerable information in the literature so can estimate time required accurately. |
| F | Audit trail | Documenting scoring can be a weakness unless 'calibrated' (indicators). Essential for reproducibility. |
| G | Software availability | Good, can be done in house. Packages available for sensitivity analysis. |

AHP

| | | |
|---|---|---|
| A | Consistency/Logical | Attributes don't need to be independent; logically sound. |
| B | Transparency | Input and outputs transparent but for more complex cases can be 'black box' re. process. |
| C | Ease of use | More complex problems require software support for large number of options, attributes. Non-linear preferences not allowed. Onerous to introduce new options. |
| D | Data requirements | Strength – doesn't need much data. |
| E | Analysis requirements | Can be split into analysis teams (also true of other techniques); sensitivity analysis more difficult to perform. |
| F | Audit trail | OK – but need to record basis of ranking options (relative scores). |
| G | Software availability | Many available and can program in-house. |

OUTRANKING

| | | |
|---|---|---|
| A | Consistency/Logical | Can have unexpected ranking changes on small changes in preferences; attributes must be independent. |
| B | Transparency | Not always obvious how output is arrived at from input. May be need for graphical representation to interpret. May be perceived as ‘black box’. Data processing high. |
| C | Ease of use | Like pair-wise but have to define additional ‘shape’ functions; more of a ‘backroom’ approach needed. Not suitable for many stakeholders. |
| D | Data requirements | OK: can be scaled according to need. |
| E | Analysis requirements | Sensitivity study very difficult – requires specific expertise to undertake and understand output. |
| F | Audit trail | Need to record basis of all parameters used, can be difficult, would require sensitivity study. |
| G | Software availability | Software package and instruction highly desirable. |

Appendix 4

MCDA Criteria – indicative list

1. Minimise Risk to Health and Safety:

- Public Health and Safety
- Worker Health and Safety

2. Maximise Security of Hazardous Materials

- Difficulty in accessing radioactive materials
- Amount of transport required

3. Minimise Environmental Impact:

- Radioactive pollution
- Chemical pollution
- Noise/traffic/dust/odour/visual/amenity impact
- Ecological disturbance
- Non-renewable resource usage
- Impact on natural and cultural heritage
- Impact on local infrastructure

4. Maximise Positive Economic Impact:

- Employment
- Impact on skills and knowledge base

5. Minimise Cost

- Research and Development cost
- Implementation cost
- Operational cost
- Closure cost

6. Maximise Stakeholder Acceptance:

- Local public
- Regulators
- Wider public interest groups
- Nuclear industry interest groups
- Academia

7. Maximise Technology/Methodology Performance:

- Technical Risk (proven technology, practicality of deployment at industrial scale)
- Technology/Methodology Operability[1]

[1] To include consideration of: versatility, flexibility, simplicity, robustness, efficiency, predictability, compactness and product quality.

Appendix 5

Strengths and Weaknesses of Leading MCDA Techniques

| Method | Description | Strengths | Weaknesses |
|---|---|---|---|
| Multi-attribute utility theory (MAUT) and Simple Multi-attribute Rating Technique (SMART) | Expression of overall performance of an alternative in a single non-monetary number representing the utility of that alternative.<br><br>Criteria weights often obtained by directly surveying stakeholders. | Easier to compare alternatives whose overall scores are expressed as single numbers.<br><br>Choice of an alternative can be transparent if highest scoring alternative is chosen.<br><br>Based on utilitarian philosophy.<br><br>Many people prefer to express net utility in non-monetary terms. | Maximisation of utility may not be important to decision makers.<br><br>Criteria weights obtained through less rigorous stakeholder surveys may not accurately reflect stakeholder's true preferences.<br><br>Rigorous stakeholder preference elicitations can be expensive. |
| Analytical Hierarchy Process (AHP) | Criteria weights and scores are based on pair-wise comparisons of criteria and alternatives, respectively. | Pair-wise comparison is easier for the decision maker(s) to undertake than comparing many options simultaneously. | The weights obtained from pair-wise comparisons may not reflect people's true preferences.<br><br>Mathematical procedures use to generate summary scores can sometimes produce illogical results. |
| Outranking | One option outranks another if it performs the other on enough criteria of sufficient importance as reflected by the sum of criteria weights) and is not outperformed by the other in the sense of | Does not require the reduction of all criteria to a single unit.<br><br>Explicit consideration of possibility that very poor performance on a single criterion may | Does not always take into account whether over-performance on one criterion can make up for under performance on another.<br>The algorithms used in outranking are often relatively |

| Method | Description | Strengths | Weaknesses |
|---|---|---|---|
| | recording a significantly inferior performance on any one criterion.<br><br>Allows options to be classified as incomparable | eliminate an alternative from consideration even if that criterion's performance is compensated for by very good performance on other criteria. | complex and not well understood by decision makers. |
| Linear Additive | Option value scores are multiplied by the criteria weights and the weighted scores added. | Well established<br><br>Robust and effective on wide range of problems. | Uncertainty not formally built in (but can be appended)<br><br>Variety of circumstances in which decision support is required has led to development of more sophisticated models. |
| Non-compensatory methods | Range of methods which compare options against common set of criteria without allowing any compensation between criteria strong vs. weak. | Uses elementary techniques so can be implemented rapidly. | Lack of compensation restricts application to simple cases. |
| Ideal Point | Options are ranked according to their separation from an ideal point. | Identify best alternative quickly. | Not in widespread use. |