EIA PROCEDURE

THE RAPID IMPACT ASSESSMENT MATRIX (RIAM) FOR EIA

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The rapid impact assessment matrix (RIAM) is a new tool for execution of an environmental impact assessment (EIA). Many traditional methods of EIA have produced large reports setting out the subjective judgments reached by the assessors. RIAM uses a structured matrix to allow for such judgments (both subjective and those based on quantitative data) to be made on a like-by-like basis, and provides a transparent and permanent record of the judgments made. The computerized RIAM system allows for the matrix to be shown in graphical form, which greatly enhances the clarity of the results produced by this method. RIAM provides a system by which development options and scenarios can be rapidly evaluated. To illustrate the use of RIAM, an example from an EIA study on fly ash deposition into landfill is given. The criteria that might be used to evaluate EIA methods, and how RIAM measures up against these criteria, are discussed.

Introduction

The rapid impact assessment matrix (RIAM) is a tool to organize, analyze and present the results of a holistic environmental impact assessment (EIA). RIAM provides a transparent and permanent record of the analysis process while at the same time organizing the EIA procedure, which in turn considerably reduces the time taken in executing EIAs (Pastakia 1998). The simple, structured form of RIAM allows reanalysis and in-depth analysis of selected components in a rapid and accurate manner. This flexibility makes the method a powerful tool for both executing and evaluating EIAs.

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RIAM has the capability to make multiple "runs" to compare different options. RIAM is able to compare (on an common basis) judgments made in different sectors as the methods follow a defined set of judgment rules. The scales in RIAM allow both quantitative and qualitative data to be assessed.

The flexibility that RIAM provides, coupled with its graphical presentation of the results of the RIAM matrix, makes this a powerful tool for executing and evaluating impact assessments.

RIAM provides the solutions to a number of criticisms that have affected EIAs since their near-universal acceptance as a necessary part of the development planning process. These criticisms have focused largely on the subjectivity of many EIAs (especially "holistic" EIAs) and the inability of these assessments to provide a record of the judgments made that is both simple and transparent.

The concepts of RIAM were developed by Pastakia (1998), but were not immediately published until the methods had been rigorously used and tested in the field (K. Jensen 1998). The first published RIAM project was on the EIA for tourism development (Madsen et al. 1993) and the RIAM concept placed in the public record in 1995 (Pastakia and Madsen 1995). The practical method is still in its early stages of development and is capable of further expansion and refinement (which is the basis of ongoing research).

Shortcomings of Existing EIA Methods

The main criticisms of EIAs are, in part, a natural result of the traditional methods used. Concerns are expressed that EIA judgments are subjective, either in whole or in part. This is a consequence of many factors: the lack or inadequacy of baseline data; the time frame provided for data acquisition and analysis; the terms of reference provided for the EIA, and the capacity of the assessors to cover a wide range of issues. Even where quantitative environmental data are available, the overall use of this data requires a subjective judgment of the possible impact, its spatial scale, and potential magnitude. It is this forecasting of events that underpins the subjectivity of the analysis.

A second major criticism relates to the difficulty of ensuring some degree of transparency and objectivity in these qualitative assessments of the impacts of projects (in particular development projects where data may be scarce and implementation may take many years). EIA evaluations need to be reassessed with the passage of time, and the data contained therein should be open to scrutiny and revision as new data become available. Wholly subjective and descriptive systems are not easily capable of such revision, dependent as they are on the expertise and experience of the original assessors and on the quality of the descriptive record left behind.

The historical development of EIA shows that a number of attempts have been made to improve the quality of the EIA analysis by seeking to improve the accuracy of the judgment, resulting in a number of formats being developed for analysis in EIA (Bisset 1988; Wathern et al. 1986).

Systems were developed that provided numerical values for subjective judgments (Bisset 1978; Leopold et al. 1971). The problems with these systems is that the reasons behind a subjective judgment remain locked behind a stated value; thus, it is impossible (without direct access to the assessor) to determine the reasoning behind the judgment made.

Subjectivity in itself is not a bar to the use or reliance of EIA; for comparison of alternative systems it is a valid system for decision-making, provided that such comparisons are made on an equal basis. The problems with subjective judgments lie in their lack of transparency and in the clarity of the historic, written record. Judgments made on quantitative measurements are simple to record, as the measurements themselves provide the evidence as to how a judgment was reached. This transparency and permanence of records become even more important when the judgment is subjective, i.e., based on the opinion of the assessor. Traditional methods have not been able to provide good records of the reasoning of this assessment.

Improvement to Traditional EIA Methods

The problem of recording the arguments that lead to a conclusion in a subjective judgment can be addressed by defining precisely how that judgment will be made. For the subjectivity of judgment to become transparent, it will be necessary to define very carefully how the analysis should be carried out and the criteria by which judgments are made. This requires that the criteria for judgment can be identified and accepted in all forms of EIA.

Many of the criteria used at present to determine what impacts may occur as a result of a development strategy or project are well known and accepted by most workers in the field of EIA. For instance, in any EIA, it is always necessary to consider the area likely to be affected; the degree or magnitude of the impact, whether the change is permanent or temporary in nature; whether the affect may be reversed; whether an impact may, with other effects, be synergistic; and whether there is any likelihood for a cumulative effect to develop over time.

All these criteria form areas of judgment common to most EIAs today, yet most assessors develop the scales for describing their judgments of the impacts against each of these criteria on an “ad hoc” basis. If, however, these criteria and scales are laid down prior to the analysis and are common to all EIA judgments, then a system for understanding the arguments by which conclusions are reached can be recorded. This understanding of the universal nature of environmental evaluation is at the heart of the RIAM concept.

The Rapid Impact Assessment Matrix

The RIAM concept has been defined by Pastakia (1998); parts of the concept paper are reproduced here for clarity. The RIAM method is based on a standard definition of the important assessment criteria, as well as the means by which semi-quantitative values for each of these criteria can be collated, to provide an accurate and independent score for each condition. The impacts of project activities are evaluated against the environmental components, and for each component a score (using the defined criteria) is determined, which provides a measure of the impact expected from the component.

The important assessment criteria fall into two groups:

(A) Criteria that are of importance to the condition, that individually can change the score obtained, and
(B) Criteria that are of value to the situation, but should not individually be capable of changing the score obtained.

The value ascribed to each of these groups of criteria is determined by the use of a series of simple formulae. These formulae allow the scores for the individual components to be determined on a defined basis.

The scoring system requires simple multiplication of the scores given to each of the criteria in group (A). The use of multiplier for group (A) is important, for it immediately ensures that the weight of each score is expressed, whereas simple summation of scores could provide identical results for different conditions.

Scores for the value criteria group (B) are added together to provide a single sum. This ensures that the individual value scores cannot influence the overall score, but that the collective importance of all values group (B) are fully taken into account.

The sum of the group (B) scores are then multiplied by the result of the group (A) scores to provide a final assessment score (ES) for the condition. The process for the RIAM in its present form can be expressed:

$$(a1) \times (a2) = aT \tag{1}$$

$$(b1) + (b2) + (b3) = bT \tag{2}$$

$$(aT) \times (bT) = ES \tag{3}$$

where (a1)(a2) are the individual criteria scores for group (A); (b1)(b2)(b3) are the individual criteria scores for group (B); aT is the result of multiplication of all (A) scores; bT is the result of summation of all (B) scores; and ES is the environmental score for the condition.

Assessment Criteria

The judgments on each component are made in accordance with the criteria and scales shown in Table 1.

Environmental Components

RIAM requires specific assessment components to be defined through a process of scoping, and these environmental components fall into one of four categories, which are defined as follows:

TABLE 1. Assessment Criteria

Criteria	Scale	Description
A1: Importance of condition	4	Important to national/international interests
	3	Important to regional/national interests
	2	Important to areas immediately outside the local condition
	1	Important only to the local condition
	0	No importance
A2: Magnitude of change/effect	+3	Major positive benefit
	+2	Significant improvement in status quo
	+1	Improvement in status quo
	0	No change/status quo
	−1	Negative change to status quo
	−2	Significant negative disbenefit or change
	−3	Major disbenefit or change
B1: Permanence	1	No change/not applicable
	2	Temporary
	3	Permanent
B2: Reversibility	1	No change/not applicable
	2	Reversible
	3	Irreversible
B3: Cumulative	1	No change/not applicable
	2	Non-cumulative/single
	3	Cumulative/synergistic

- Physical/Chemical (PC)
  Covering all physical and chemical aspects of the environment.
- Biological/Ecological (BE)
  Covering all biological aspects of the environment.
- Sociological/Cultural (SC)
  Covering all human aspects of the environment, including cultural aspects.
- Economic/Operational (EO)
  Qualitatively to identify the economic consequences of environmental change, both temporary and permanent.

To use the evaluation system described, a matrix is produced for each project option, comprising cells showing the criteria used, set against each defined component. Within each cell the individual criteria scores are set down. From the formulae given previously, ES number is calculated and recorded.

No claim is made for the sensitivity of any ES value. To provide a more certain system of assessment, the individual ES scores are banded together into ranges where they can be compared. Ranges are defined by conditions that act as markers for the change in bands. The full reasons for the setting of range bands is described by Pastakia (1988). Table 2 gives the ES values

TABLE 2. Conversion of Environmental Scores to Range Bands

Environmental Score	Range Bands	Description of Range Bands
+72 to +108	+E	Major positive change/impacts
+36 to +71	+D	Significant positive change/impacts
+19 to +35	+C	Moderately positive change/impacts
+10 to +18	+B	Positive change/impacts
+1 to +9	+A	Slightly positive change/impacts
0	N	No change/status quo/not applicable
−1 to −9	−A	Slightly negative change/impacts
−10 to −18	−B	Negative change/impacts
−19 to −35	−C	Moderately negative change/impacts
−36 to −71	−D	Significant negative change/impacts
−72 to −108	−E	Major negative change/impacts

and range bands currently used in RIAM. The final assessment of each component is evaluated according to these range bands.

Once the ES score is set into a range band, these can be shown individually or grouped according to component type and presented in whatever graphical or numerical form the presentation requires.

RIAM in Use: The Esbjerg Fly Ash Landfill

The County of Ribe and the Danish power company Vestkraft I/S accepted that the proposed new fly ash landfill at the power station Vestkraft I/S in Esbjerg could be used as a test case for the RIAM.

Project Background

Power production at Vestkraft I/S is based on coal, imported from different coal mines with varying contents of trace elements. The burning of coal produces several waste products: bottom ash from the furnace, fly ash from the dust collection system (electrostatic precipitators), and gypsum from the flue gas cleaning system. The majority of the waste products are reused, e.g., fly ash in cement production and road construction, bottom ash in road construction and gypsum in production of plasterboard. It is not possible to reuse the fly ash completely, which is the largest waste quantity produced. The fly ash contains different trace elements, with arsenic (As), chromium (Cr), selenium (Se), molybdenum (Mo), and vanadium (V) being the elements with the major environmental problems, because they may be leached from the fly ash.

Fly ash has been deposited (since the end of the 1970s) in landfills (phases I–III) along the coastline of the Wadden Sea (Figure 1). The embankment (phase III) in the sea (at 0–0.6 m depth) was constructed from sand, covered with fiber textile and rubble. These filled landfills have become part of the

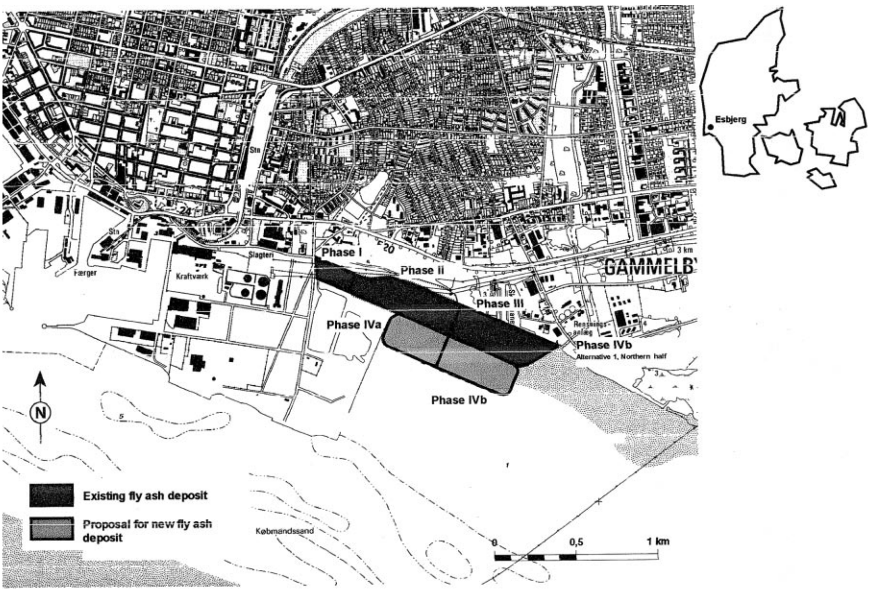

FIGURE 1. Map showing the Esjberg project site.

harbor area. A new landfill or another site for deposition of fly ash must be established, because the existing landfills are now full.

The Political Decision Process

Several different locations in the County of Ribe for establishment of a new landfill were assessed initially by the County and Vestkraft, with the conclusion that two sites were suitable:

- An area south of Esbjerg, where Esbjerg Community already has a dump site for garbage, and where it is possible to deposit waste up to a height of 30 m above ground level;
- The area—phases IVa and IVb in Figure 1—south of the existing landfill.

The assessment revealed that the landfill site, phase IV, was the most suitable location so the area close to the Esbjerg site was not assessed in such detail as was the Phase IV option. The EIA concentrated solely on the landfill site.

Objective of the Study

The objective of the study was to test RIAM on the data collected in connection with the EIA and related environmental studies for phase IV of the landfill. The aim was to investigate the usefulness of the RIAM as a tool in projects requiring an EIA according to the European Union Council Directive (1997).

Description of the Study

The study was executed for the landfill, development phase IV, as described by I/S Vestkraft (1997), and Ribe Amt (1997a, 1997b, and 1997c). Five different options for phase IV were tested, with different degrees of collection and treatment of the leachate from the landfill:

Option 1: Phase IV would be constructed in the same way as phase III, as described by ELSAMPROJEKT A/S (1987). Phase III was constructed with an embankment, but without a drainage system for collection of leachate either in the bottom or at the surface of the filled landfill. The precipitation therefore leaches through the ash to the sea through the embankment of the landfill. In addition, leachate from the old landfills may penetrate into the new landfill. This option was used as the reference study (baseline solution) for the other phase IV options.

Options 2–5: The embankment is constructed as in option 1. However, a drainage system is built at the bottom of the landfill and along the embankment, so that it is possible to collect, control, and treat all leachate. The landfill will be filled in subsections with drainage systems, so that the leachate can be collected when deposition is started. Leachate from the old landfills (phases II and III) will penetrate into the new landfill and will be collected in the drainage system.

The following describes the differences between options 2–5:

Option 2: Collection of leachate from the start of phase IV with direct discharge—by pumping—of the leachate into the channel that transports cooling water from the power plant to the sea, where the leachate is extensively diluted.

Option 3: At the beginning, leachate is discharged as in option 2. After some time, when the leachate contains higher concentrations of pollutants, it will be treated in a new treatment plant (coprecipitation technique) for removal of harmful substances (especially As, Cr, Mo, Se, and V). Effluent from the treatment plant will be discharged into the channel that transports cooling water from the power plant to the sea. Sludge containing the trace elements will be transported to a special landfill (at Kommunekemi) for hazardous waste products.

Option 4: Diffuse leaching (by not pumping) directly into the sea through the embankment of the landfill. After some time, when the leachate contains higher concentrations of pollutants, it will be treated as in option 3.

Option 5: Collection of leachate (as in option 2). After some time, when the leachate contains higher concentrations of pollutants, it will be reused as make-up water in the desulphurization plant, thus saving the groundwater resources. Leachate will be injected directly to the absorption tower of the desulphurization plant. When the concentrations of pollutants in the absorption water are too high, it will be discharged to the treatment plant of the desulphurization unit and afterwards to the new treatment plant (coprecipitation technique) for removal of harmful substances (especially As, Cr, Mo, Se, and V). The effluent from this second treatment plant will be discharged to the municipal sewer due to the content of nitrate coming from the desulphurization plant. The sludge from the existing treatment plant today is mixed with coal and burnt in the power plant; it is hoped that the new sludge can be treated in the same way. The sludge from the coprecipitation plant, containing As, Cr, Mo, Se, and V, will be transported to the special landfill at Kommunekemi if it cannot be burnt with the coal.

Scoping

The components used for the EIA were determined; the scoping includes all five options with 13 physical/chemical (PC), 12 biological/ecological (BE), 2 social/cultural (SC), and 9 economical/operational (EO) components. The components and the scoring for options 1 and 5 are shown in the RIAM matrix (Table 3).

RIAM Analysis

Figure 2 shows the graphical summary of the RIAM analysis. The figure shows that the most positive impacts can be expected by selection of option 5 compared to the other options. Option 1 has only neutral or negative impacts. The positive impacts in option 5 offset negative EO impacts, due to the higher investment, operation, and maintenance costs.

Option 1 was taken as the baseline situation. To further compare options 1 and 5, a scenario was run through the RIAM system to demonstrate the difference in impacts between the baseline solution and the option with the most positive impacts. Figure 3 demonstrates that option 1 has mainly neutral impacts, no positive impacts and negative impacts for components:

- PC4: leaching from the existing fly ash landfill into the new landfill,
- PC5: leaching to the sea through the embankments,
- PC7: leaching to the groundwater,
- BE1: effects in the sea by diffuse leaching through the embankments,
- BE6: effects on ground water,
- BE12: leaching to the sea from old landfills of fly ash,
- SC1: dust from landfill affecting the nearby housing,
- SC2: noise from landfill affecting nearby housing.

The negative impacts for option 5 include:

- PC14: deposition of sludge from treatment plant at Kommunekemi,

TABLE 3. RIAM Analysis Matrix and Summary (Options 1 and 5)

Components	ES	RB	A1	A2	B1	B2	B3
Option 1: Phase III landfill used as baseline solution							
Physical/Chemical Components							
PC1 Construction of the embankment, dredging of the bottom/sheet piling, reduction in leaching from and to the sea	0	N	0	0	1	1	1
PC2 Construction of smaller embankments within the landfill, reduction in leaching in unused landfill	0	N	0	0	1	1	1
PC3 Drainage of the surface soil with direct discharge to the sea	0	N	0	0	1	1	1
PC4 Leaching from the existing fly ash landfill into the new landfill	−6	−A	1	−1	3	2	1
PC5 Leaching to the sea through the embankments	−54	−D	2	−3	3	3	3
PC6 Collection of leachate in a drainage system in the bottom of the landfill	0	N	0	0	1	1	1
PC7 Leaching to the groundwater	−18	−B	2	−1	3	3	3
PC9 Sprinkler equipment for watering of deposited fly ash for reduction of dust	0	N	0	0	1	1	1
PC10 Collection of leachate and pumping to channel for cooling water	0	N	0	0	1	1	1
PC11 Use of leachate as make-up water in desulphurization plant	0	N	0	0	1	1	1
PC12 Treatment of the leachate in a special treatment for the removal of As, Cr, Se, Mo, and V	0	N	0	0	1	1	1
PC13 Discharge of reused and treated leachate to the municipal sewage treatment plant	0	N	0	0	1	1	1

(*Continued*)

TABLE 3. (*Continued*)

Components		ES	RB	A1	A2	B1	B2	B3
PC14	Deposition of sludge from treatment plant at Kommunekemi	0	N	0	0	1	1	1
Biological/Ecological Components								
BE1	Effects in the sea by diffuse leaching through the embankment	−54	−D	2	−3	3	3	3
BE2	Effects in the sea with discharge into the cooling water channel of leachate without treatment	0	N	0	0	1	1	1
BE3	Effects in the sea with discharge into the cooling water channel of treated leachate	0	N	0	0	1	1	1
BE4	Effects in the sea with special removal of As, Cr, Se, Mo, and V	0	N	0	0	1	1	1
BE5	Effects in the sea of the construction of a drainage system along the embankment	0	N	0	0	1	1	1
BE6	Effects on ground water	−18	−B	1	−2	3	3	3
BE8	Effects from construction of smaller embankments within the landfill	0	N	0	0	1	1	1
BE9	Effects of the drainage system at the surface of the filled landfill	0	N	0	0	1	1	1
BE10	Effects on ground water resources on reuse of leachate in the desulphurization plant	0	N	0	0	1	1	1

(*Continued*)

TABLE 3. (*Continued*)

Components		ES	RB	A1	A2	B1	B2	B3
BE11	Effects in the sea when leachate cannot be diluted with cooling water in the channel	0	N	0	0	1	1	1
BE12	Leaching to the sea from old landfills of fly ash	−36	−D	2	−2	3	3	3
BE13	Effects in the sea when treated leachate cannot be diluted with cooling water	0	N	0	0	1	1	1
Social/Cultural Components								
SC1	Dust from landfill affecting nearby housing	−24	−C	2	−2	3	2	1
SC2	Noise from landfill affecting nearby housing	−36	−D	2	−3	3	2	1
Economic/Operational Components								
EO2	Construction costs of embankment with dredging/sheet piling	0	N	0	0	1	1	1
EO3	Construction costs of smaller embankment within the landfill	0	N	0	0	1	1	1
EO4	Construction costs of surface drainage system	0	N	0	0	1	1	1
EO5	Construction costs for drainage system in the bottom of the landfill	0	N	0	0	1	1	1
EO6	Costs of sprinkler equipment for watering of fly ash in the landfill	0	N	0	0	1	1	1
EO7	Costs for collection of leachate and pumping to cooling channels	0	N	0	0	1	1	1
EO8	Costs (savings) by use of leachate in the desulphurization plant	0	N	0	0	1	1	1
EO9	Costs of treatment plant for removal of As, Cr, Se, Mo, and V	0	N	0	0	1	1	1

(*Continued*)

TABLE 3. (*Continued*)

Components		ES	RB	A1	A2	B1	B2	B3
EO10	Costs for deposition of sludge from treatment plant at Kommunekemi	0	N	0	0	1	1	1

Summary of Scores

Class	−E	−D	−C	−B	−A	N	A	B	C	D	E
PC	0	1	0	1	1	10	0	0	0	0	0
BE	0	2	0	1	0	9	0	0	0	0	0
SC	0	1	1	0	0	0	0	0	0	0	0
EO	0	0	0	0	0	9	0	0	0	0	0
Total	0	4	1	2	1	28	0	0	0	0	0

Option 5: Collection of leachate from the beginning of phase IV with discharge to cooling water channel. Later reuse of leachate.

Physical/Chemical Components

Components		ES	RB	A1	A2	B1	B2	B3
PC1	Construction of the embankment, dredging of the bottom/sheet piling, reduction in leaching from and to the sea	7	A	1	1	3	3	1
PC2	Construction of smaller embankments within the landfill, reduction in leaching in unused landfill	10	B	1	2	2	2	1
PC3	Drainage of the surface soil with direct discharge to the sea	7	A	1	1	3	3	1
PC4	Leaching from the existing fly ash landfill into the new landfill	16	B	1	2	3	2	3
PC5	Leaching to the sea through the embankments	0	N	0	0	1	1	1
PC6	Collection of leachate in a drainage system in the bottom of the landfill	48	D	2	3	3	2	3
PC7	Leaching to the groundwater	32	C	2	2	3	2	3

(*Continued*)

TABLE 3. (*Continued*)

Components		ES	RB	A1	A2	B1	B2	B3
Physical/Chemical Components								
PC9	Sprinkler equipment for watering of deposited fly ash for reduction of dust	24	C	2	2	3	2	1
PC10	Collection of leachate and pumping to channel for cooling water	18	B	1	3	3	2	1
PC11	Use of leachate as make-up water in desulphurization plant	6	A	1	1	3	2	1
PC12	Treatment of the leachate in a special treatment for the removal of As, Cr, Se, Mo, and V	7	A	1	1	3	3	1
PC13	Discharge of reused and treated leachate to the municipal sewage treatment plant	6	A	1	1	3	2	1
PC14	Deposition of sludge from treatment plant at Kommunekemi	−54	−D	3	−2	3	3	3
Biological/Ecological Components								
BE1	Effects in the sea by diffuse leaching through the embankment	0	N	0	0	1	1	1
BE2	Effects in the sea with discharge into the cooling water channel of leachate without treatment	0	N	0	0	1	1	1
BE3	Effects in the sea with discharge into the cooling water channel of treated leachate	8	A	1	1	3	2	3
BE4	Effects in the sea with special removal of As, Cr, Se, Mo, and V	36	D	2	2	3	3	3
BE5	Effects in the sea of the construction of a drainage system along the embankment	36	D	2	2	3	3	3

(*Continued*)

TABLE 3. (*Continued*)

Components		ES	RB	A1	A2	B1	B2	B3
BE6	Effects on ground water	9	A	1	1	3	3	3
BE8	Effects from construction of smaller embankments within the landfill	7	A	1	1	2	2	3
BE9	Effects of the drainage system at the surface of the filled landfill	9	A	1	1	3	3	3
BE10	Effects on ground water resources on reuse of leachate in the desulphurization plant	12	B	2	1	3	2	1
BE11	Effects in the sea when leachate cannot be diluted with cooling water in the channel	0	N	0	0	1	1	1
BE12	Leaching to the sea from old landfills of fly ash	32	C	2	2	3	2	3
BE13	Effects in the sea when treated leachate cannot be diluted with cooling water	0	N	0	0	1	1	1
Social/Cultural Components								
SC1	Dust from landfill affecting nearby housing	−12	−B	2	−1	3	2	1
SC2	Noise from landfill affecting nearby housing	−24	−C	2	−2	3	2	1
Economic/Operational Components								
EO2	Construction costs of embankment with dredging/sheet piling	−12	−B	1	−2	2	3	1
EO3	Construction costs of smaller embankment within the landfill	−6	−A	1	−1	2	3	1
EO4	Construction costs of surface drainage system	−6	−A	1	−1	3	2	1
EO5	Construction costs for drainage system in the bottom of the landfill	−12	−B	1	−2	2	3	1

(*Continued*)

TABLE 3. (*Continued*)

Components		ES	RB	A1	A2	B1	B2	B3
EO6	Costs of sprinkler equipment for watering of fly ash in the landfill	−12	B	1	−2	2	3	1
EO7	Costs for collection of leachate and pumping to cooling channels	−12	−B	1	−2	3	2	1
EO8	Costs (savings) by use of leachate in the sulphurization plant	9	A	1	1	3	3	3
EO9	Costs of treatment plant for removal of As, Cr, Se, Mo, and V	−27	−C	1	−3	3	3	3
EO10	Costs for deposition of sludge from treatment plant at Kommunekemi	−14	−B	1	−2	3	3	1

Summary of Scores

Class	−E	−D	−C	−B	−A	N	A	B	C	D	E
PC	0	1	0	0	0	1	5	3	2	1	0
BE	0	0	0	0	0	4	4	1	1	2	0
SC	0	0	1	1	0	0	0	0	0	0	0
EO	0	0	1	5	2	0	1	0	0	0	0
Total	0	1	2	6	2	5	10	4	3	3	0

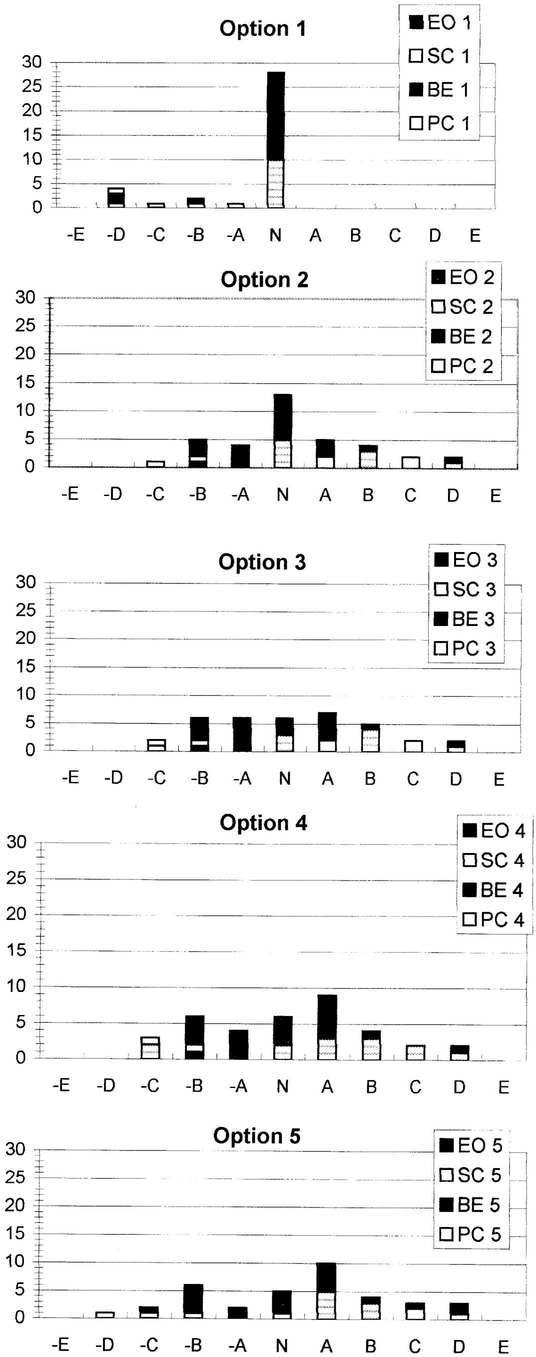

FIGURE 2. Summary of RIAM analysis (options 1–5). Y-axis: number of components (all graphs).

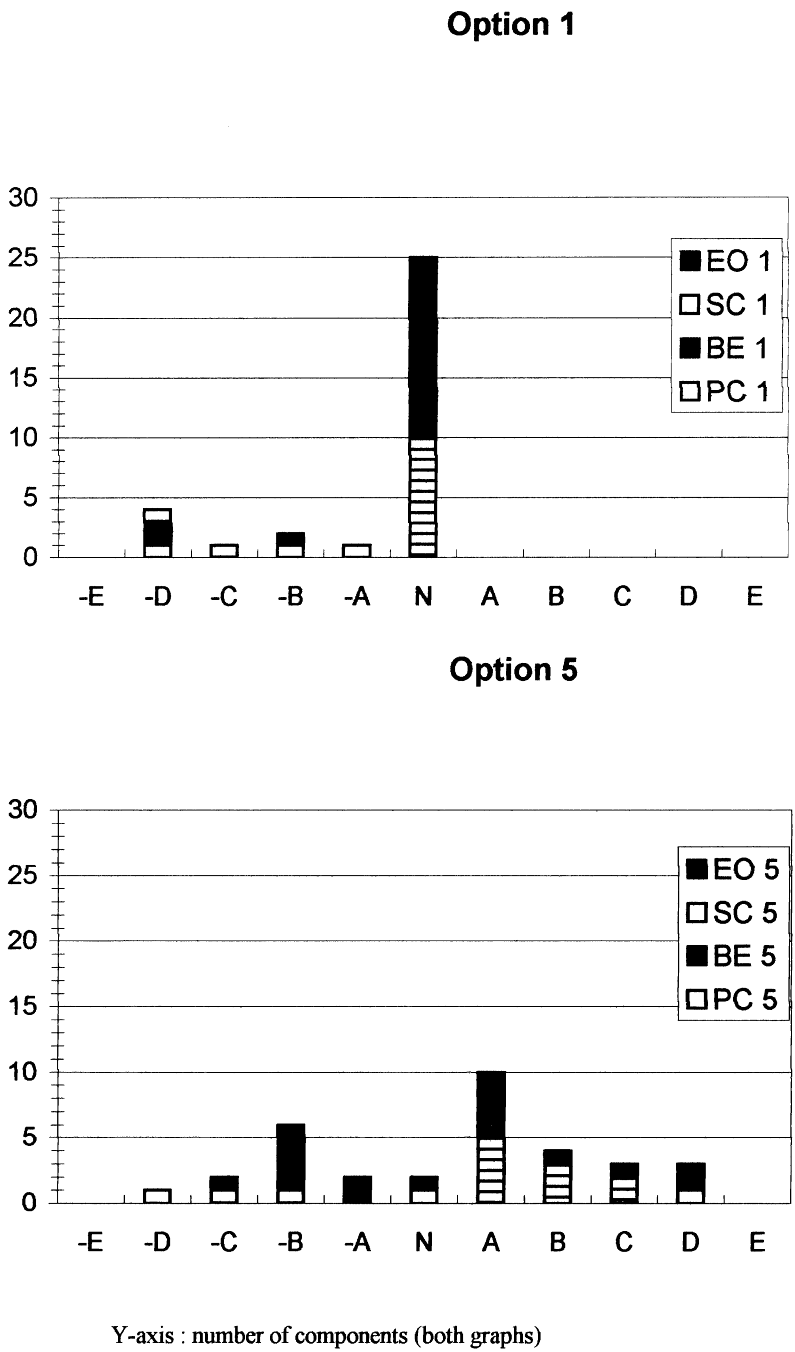

FIGURE 3. Summary of RIAM analysis (options 1 and 5).

- SC1: dust from the landfill affecting nearby housing,
- SC2: noise from the landfill affecting nearby housing,
- All the EO components except EO8 [Costs (savings)] by use of leachate in desulphurization plant.

Discussion of Results of RIAM Analysis

The study has shown that option 1 (baseline solution) has no impacts or negative impacts, due to direct leaching into the sea from the new as well as from the old landfills. On the other hand, it is the least costly solution, and the investment, operation, and maintenance cost are significantly higher for options 2–5 (giving negative impacts for these components compared with option 1). The major positive impacts of options 2–5 compared with option 1 are the pumping out of the leachate with discharge into the cooling channel where it is immediately diluted, so that possible effects in the sea are restricted to a small area. There is very little difference between the impacts of options 3 and 4.

Option 5 is the optimal solution with the least negative impacts, because leachate is only discharged during the start-up period into the cooling channel, where the concentrations of harmful substances are so low that no impacts are expected in the sea. After the initial period, the leachate would be reused in the desulphurization plant, saving groundwater resources. Reused leachate would be processed in a special treatment plant. The effluent from the treatment plant would be discharged to the municipal treatment plant, due to high concentrations of nitrate. The negative impacts of option 5 are the high investment and operation costs and the deposition of the sludge from the treatment plant into a special landfill for hazardous waste. The impacts of option 5 could be reduced further if the leachate is reused when it is first produced. This solution allows no discharge to the sea except of treated effluent from the municipal treatment plant. It is expected that this effluent contains very low concentrations of pollutants.

Comparison of the RIAM with Other EIA Methods

To compare methods one has to be able to define the criteria against which the value of each method may be judged. For EIA these criteria should include:

- Cost of the method
- Time required for the method
- Accuracy of the results
- Transparency of the results
- Permanence of the record
- Clarity of the results
- Replicability of the method
- Universality of use.

RIAM is cost effective when set against traditional EIA systems. Because of its ordered manner, it is possible to set up the procedures in a planned way, which in turn can often lead to a more accurate forecast of the necessary budget. The method has been computerized (VKI 1998), which allows rapid analysis to take place. Because of its ability to use qualitative data, the method can be pursued at different levels in the development cycle, and so provide guidance on possible positive and negative impacts in a more continuous manner than with other methods.

The picture built up by the RIAM, in the matrix values and in the resulting histograms, is a true representation of judgments made by the assessors. A further value of RIAM is that the scales used for each criterion are defined. As a result, subjective judgments are understood by the reader of the report, not merely (as in many methods) as "high," "moderate," or "low."

This accuracy is related to, and evident in, the transparency of the RIAM record. Each criterion, for each component, has a judgment recorded by a figure, which in turn is predefined. The reader of any RIAM EIA report can immediately understand, from the RIAM matrix, the exact value ascribed by the assessor to any cell in the matrix.

This record is permanent. It provides at any time in the future a complete statement of the judgments made by the assessor in an EIA. This record of judgments enables procedures in RIAM to be rechecked easily. Work can be redone or the options reappraised with relative ease and a high confidence of accuracy. The replicability of the system is thus very good.

Whether RIAM is, in its present form, a universally applicable method for EIA is yet to be proven, The method is certainly very good for early EIA screening and for initial environmental evaluations (IEEs) (Jensen et al. 1988; Pastakia and Bay 1998). With respect to full EIAs, it has been successfully used on projects relating to flood damage assessment (Hagebro 1998), sewage disposal (A. Jensen 1998), and tourism development (Madsen et al. 1993). Present evidence suggests that the method is acceptable for all projects requiring EIAs that involve water, wastewater, and tourism development, and the method is being considered for forestry and other resource exploitation situations.

No similar tool has been published, to the authors' knowledge. However, a recent study (Mohorjy and Aburizaiza 1997) has used the Delphi approach to identify and evaluate systematically the impacts of effluent control system in Jedda, Saudi Arabia. In this study, a panel consisting of up to 350 respondents with special expertise was requested to give their opinion on 17 different impacts related to this problem in Jedda. The respondents were asked to assess/interpret the impacts and rank them according to the following criteria: importance, magnitude, probability, urgency, type, range and nature of impact (reversible/irreversible). The impacts answered by the respondents were ranked by use of a statistical analysis.

Both studies—although quite different—have shown that systematic ranking possible impacts makes the decision process transparent and open to changes in the rating of the impacts to demonstrate sensitivity effects.

Conclusions

RIAM is a very powerful tool to use in an EIA, especially with very complex options as demonstrated in this study. It is transparent, able to test different options easily, and still able to obtain an overview of the solutions. It is easy to visualise the results of different options, which makes the tool useful for decision makers.

The fly ash study has tested RIAM in Denmark, and it has shown that RIAM is a very useful and transparent tool to apply when implementing the European Union Directive on EIA. It also demonstrates the efficiency of the RIAM tool in handling cases with large quantities of data, which can make it difficult to obtain an overview of the results.

The ability of RIAM to provide a clear, transparent, and permanent record of the judgments made in an EIA is a major advance in improving the use of EIA. It is hoped that the RIAM concept, and the ease of use of the method, may lead to a wider acceptance of impact assessment in all stages of development planning and management.

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