Decision making in environmental management

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Summary
Decision making in environmental management often leads to several problems. In this paper we concentrate on the selection of proper alternatives. These problems can be solved by a proper development of DSS as is shown in two examples. The first example is a DSS that supports choices between different soil remediation alternatives by taking into account risk reduction, environmental merit and costs. The second example is a DSS, still in development, for decisions upon Stabilisation/Solidification techniques with three fundamental objectives: financial costs, environmental damage and leaching out. The systems do not replace the decision-makers, but support them by arranging information and presenting it in an orderly fashion. It is concluded that DSS may be useful in a problem context with multiple perspectives and several actors are involved. The DSS simplifies the problem process through separation of facts from values.

Introduction and problem definition
A general model for problem solving or decision making is given by Mintzberg et al. (1976). They distinguish three main phases of decision-making: problem identification, development of problem solving alternatives and selection of the best alternative (Figure 1).

![Figure 1: A general model of decision processes (Mintzberg et al., 1976)](image)
The identification phase consists of the central routines: recognition, in which the problem is recognised and evokes decisional activity and diagnosis, in which the decision makers seek to comprehend the evoking stimuli and determine the cause-effect relations for the decision situation. The development phase contains a search routine to find ready-made solutions and a design routine to develop tailor-made solutions. Finally, the selection phase consists of a screen routine, several valuation/choice routines and an authorisation/implementation routine. In this paper we concentrate on the selection of proper alternatives for environmental problems, though we recognise that a lot of difficulties occur in the two other phases.

Decision support systems (DSS) could be useful in the selection phase. Herewith we define DSS as a tool to support stakeholders in the selection of alternatives. The goal of this paper is to describe a proper development of DSS and use of these decision support systems. Proper is defined as giving the stakeholder support in their selection of alternatives. This goal is related to the following questions:

- When is the use of decision support tools useful?
- How should such tools be developed?
- How should such tools be used in practice?

For answering the questions above we first have a short look at the decision process in environmental management and the role of DSS. Secondly we look at two decision support systems, for support in two particular areas of environmental management. The first model, Risk reduction, Environmental merit and Costs for soil remediation (REC) is almost finished. The second model, a DSS for waste management is still in a development state. Finally we discuss the outcomes and draw conclusions.

**Decision making in environmental management and the role of DSS**

In this paragraph we first describe general problems in decision making in environmental management. Secondly we look at the possible role of DSS, so that in the next paragraph the first DSS can be introduced.

As we mentioned earlier we focus on the selection process of proper solution in environmental management. In this selection process we have to cope with three problems. Firstly, solutions for environmental problems often try to serve different objectives. In a single objective problem, for example the reduction of CO$_2$ emissions, maximisation is possible. More often solutions for environmental problems do have a positive impact on some aspects, but have adverse effects on others. For example, soil remediation serves the improvement of soil quality, but also gives emissions to the air through using (fossil) energy. Not only the signs of the objectives sometimes contrast, but often these objectives also differ in scale and time.

Secondly, the weighing of objectives by the different stakeholders, e.g. industry seems to focus on cost-effectiveness, while local government wants primarily the reduction of local environmental effects. So even if we know the objectives we want to serve, the valuation of these objectives is difficult, because of the different views or perspectives on these objectives by the stakeholders.

The third problem is related to demand for and availability of information. Sometimes there is an information overflow, in other complex environmental problems, there is often a lack of information. In both cases an orderly and transparent way of presenting the information in relation to the decision that has to be made, can prove to help the decision process. The problem of different objectives, valuation of objectives and information is not unique for environmental management, but more elementary because often a compromise between objectives and stakeholders is a necessity. A possible way of coping with these problems is the use of DSS.

When we have a look at the characteristics of DSS the relation with the problems mentioned above becomes clear. The following characteristics of DSS are given [Janssen]:

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provide a structure for the evaluation in order to simplify the analysis and the synthesis of large amounts of information
forces people to think thoroughly about their objectives and priorities
support the analysis of conflicts among objectives
address factual and value information
accommodate different types of information
increase transparency of the decision

In the next chapters two examples of DSS will be given. By introducing those two examples we want to look if the expectation given in the characteristics are met and if DSS can play a role in solving the problems above. In the description of these two examples we specially focus on the development process, which is an important factor for an effective DSS. The first example is related to the choice of soil remediation alternatives, and is developed within the NOBIS-program (Dutch Research Programme Biotechnological In-situ Remediation). The second example is a project, related to hazardous waste management. It is still in a developing phase. After these descriptions we will evaluate and draw conclusion in relation the questions posed above.

Risk reduction, Environmental merit and Costs (REC)

Background of soil remediation
Early estimations of the number of polluted sites in the EU were 55,000 [Merzagora]. In 1994 the predictions of contaminated sites was already over 500,000. These estimations give an insight into the extend of the problem. The demand for an effective and efficient clean-up operation seems necessary. One of the reasons for this is that the costs involved in a total clean-up of the contaminated land are not politically acceptable. Another reason is the growing recognition that clean-up operations do not necessary lead to a positive environmental balance. Soil remediation requires the use of resources (such as energy and clean water) and may lead to a net transfer of contamination to other compartments (due to, for instance, air emissions). The decision regards the choice of the right remediation alternative at a given site is one of the steps needed in providing such an effective and efficient clean-up operation.

General problem description
Soil remediation has often focused on a single perspective: reducing concentrations of the contamination below given standards, so that a high soil quality can be restored. If standards are high enough, then the soil after remediation can be used for any purpose without restrictions, because the risks due to exposure to the contamination are taken away. Although this is a very desirable outcome, experience has shown that this objective is difficult to achieve. Cost constraints and technical limitations make it difficult to restore a pristine soil in all situations.

Cleaning-up management is first of all a matter of balancing environmental achievements against reasonable costs. The impact of remediatial actions on scarce commodities as soil and energy and emissions to other compartments (like air) has seldom been addressed, but are an important issue for environmental measures as soil remediation.

Next to this, innovative technologies, like biological in-situ techniques, have difficulties reaching desired low concentrations, but are less expensive and less energy consuming. There seems to be a stagnation of the implementation of these innovative technologies, due to too much focus on the perspective of reducing the concentrations below given standards. Therefore REC (Risk reduction, Environmental merit and Cost) is developed as a DSS for the choice between different soil remediation alternatives [Beinat et al, 1998].

Actors and the DSS
Cleaning-up operations involve a number of actors, which affect, and are affected by, the decision. Figure 2 shows the main actors usually involved in a remediation project.
Those located in the centre of the network usually have the strongest influence on the selection of a remedial alternative.

The interests of different actors partly coincide and partly may be different. Table 1 illustrates the interests for the main players in the decision process for soil remediation.

Table 1: Indication of the different interests of various actors.

<table>
<thead>
<tr>
<th>Players</th>
<th>Interests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem holder</td>
<td>cost effectiveness</td>
</tr>
<tr>
<td></td>
<td>functionality of soil</td>
</tr>
<tr>
<td></td>
<td>efficient decision-making</td>
</tr>
<tr>
<td>Authorities</td>
<td>Multifunctionality of soil</td>
</tr>
<tr>
<td></td>
<td>Maximisation environmental balance</td>
</tr>
<tr>
<td></td>
<td>Consistent policy</td>
</tr>
<tr>
<td></td>
<td>Efficient decision-making</td>
</tr>
<tr>
<td>Consultants</td>
<td>Looking after the interests of the client</td>
</tr>
<tr>
<td></td>
<td>Efficient decision-making</td>
</tr>
<tr>
<td>Third parties, residents</td>
<td>risk reduction</td>
</tr>
<tr>
<td></td>
<td>minimal limitations of use</td>
</tr>
<tr>
<td></td>
<td>minimal nuisance</td>
</tr>
<tr>
<td></td>
<td>efficient decision-making</td>
</tr>
<tr>
<td>Contractor</td>
<td>Looking after the interests of the client</td>
</tr>
<tr>
<td></td>
<td>Efficient decision-making</td>
</tr>
</tbody>
</table>

Efficient decision-making is important to all actors involved. The creation of a (as far as possible) univocal picture of the main decision criteria - Risk reduction, Environmental merit and Costs - may result in better weighing of interests by the various actors involved and therefore in a more efficient decision-making process. It is evident that not all-specific interests can be represented in a general methodology. The REC system provides information on three key issues, but does not replace the...
decision-makers. The final decision will always include also subjective judgement and site-specific evaluations, which will depend on the context of the decision and on the actors which are involved.
DSS and the use of the DSS

The fundamental objectives of a soil remediation can be achieved in a number of ways, depending on the cleaning-up strategy used. The path that links the polluted site, the soil remediation operations, the consequences of remediation and their relationship with the fundamental objectives of remediation is shown in figure 3.

![Figure 3: Cause-effect chain of soil remediation.](image)

This figure shows, in a very simple fashion, the various activities that take place during remediation, their effects and their links with the objectives to be achieved. The thick-bordered boxes indicate which specific aspects are included in the R, E and C models. For instance, risk minimisation is the effect of reduced exposure. This, in turn, can be achieved by reducing the pollution at the site or by controlling the exposure path (e.g., by isolation). In any case, and as it will be explained below, what we measure in REC are the changes in exposure, which will serve as an indication of risk reductions.

The REC methodology is not an independently operating system that can replace experts or decision-makers. Instead, it supports the decision-making process by arranging information and presenting it in an orderly fashion. This helps the decision-makers understand the issues at stake and allows a clear analysis of the trade-offs, which are necessary for making a decision.

REC in practice

REC has been used in over 20 cases. In most of those cases a trivial solution was not available, and there was a contradiction in different objectives. At the moment, a systematic evaluation of these cases has not been made, however it is possible to see some trends. Firstly the DSS is appreciated for giving an insight into the contribution of the alternatives to the objectives, especially an insight in broader environmental aspects is welcomed by the actors.

Secondly some of the stakeholders say that the DSS gives a too simple picture of the problem at stake, but on the other hand some stakeholders say the system is too complex. Developers of the system recognise the problem of simplicity versus complexity, but try to balance between both.

Thirdly some stakeholders expected that the method would give one solution and not three outcomes. They hoped for a system that released them from decision-making. Though the developers emphasised on the support role for the system.
Overall the system was appreciated, but a great emphasis on the support role seems necessary, because the DSS is not meant to replace stakeholders.

**Supporting decisions in hazardous waste management**

**Background of hazardous waste management**

A project has started to design a decision support system for Stabilization/Solidification-techniques of hazardous waste materials. The backgrounds of this system are hazardous waste materials, S/S-techniques and alternatives for a Stabilized/Solidified hazardous waste material.

Due to several industrial and non-industrial processes waste is released. If the waste contains a high potential leaching out of hazardous compounds, the waste material is called hazardous. In the Netherlands, Municipal Solid Waste Incineration (MSWI), Soil remediation, water purification and sludge up of rivers produce approximately 500 Kton hazardous waste materials each year [VROM]. A possible treatment for this waste material is Stabilisation/Solidification. S/S-techniques change hazardous waste materials, physical and chemical, such that risk of dispersal of environmental pollution through leaching, erosion and dispersion in the short and long term will decrease [CUR]. Both using binders, like cement, and thermal treatment may lead to a stabilised/solidified material. This material can be dumped of with less isolation and control devices. Another alternative for stabilised/solidified materials is the replacement of primary building materials such as concrete or basalt.

**General problem description**

Waste management has often focused on three perspectives. Legislation concerning dump of waste materials and use of building materials limit the leaching out of hazardous compounds. Moreover, the Ministry of Environment presented a priority of waste management from reuse to dump. Three fundamental perspectives can be deduced from the legislation mentioned above: reduce the contamination of soil and water and decrease the use of primary materials. Though, the attempt to decrease contamination and decrease the use of primary materials is desirable, not only environmental, but also economic perspectives play a role in waste management. Moreover, environmental issues are not restricted to contamination and primary materials. For example, some treatments of waste materials are energy consuming and thereby lead more to a decrease of scarce energy resources than does the dumping of waste materials. Innovative techniques, such as Solidification/Stabilisation-techniques, may contribute to integrated waste management. In the past few years, the ministry of Environment has changed her opinion about Stabilisation/Solidification-techniques [Tuijn]. Waste management more and more aims at balancing out environmental achievements against reasonable costs. In this project a DSS for integrated choices between S/S-processes and alternative treatments of hazardous waste materials will be developed.

**Actors and the DSS**

In the previous chapter, it was said that actors in the field of clean-up operations affect, and are affected by, the decision. The same is true for actors in waste management. Figure 4 shows the main actors usually involved in the implementation of a S/S-technique. The centre of the circle contains actors who usually have the strongest influence on the selection of a treatment for and destination of hazardous waste materials.

![Diagram of actors in waste management](image-url)
Owners of hazardous waste materials choose between the use of stabilisation/solidification techniques or leave the waste material unstabilised/solidified. Examples of these owners are local authorities, MSWI-plants and industry. The DSS for waste management does not replace the decision-makers. ‘Individual’ judgements and the specific context of a certain waste management problem are included in the DSS.

**Development of the DSS**

Decisions in waste management aim at maximising the benefits of the destination of a waste material and minimising the costs. Three fundamental objectives are selected for the development of the DSS:

1. maximise financial benefits;
2. minimise environmental damage;
3. minimise leaching out of hazardous compounds.

A number of alternatives are available to achieve these objectives. However, none of them will dominate on all the perspectives. How these objectives are related to the activities and effects of S/S-treatments of hazardous waste materials is illustrated with figure 5 and table 3.
Figure 5: Cause-effect chain of the pathway from release of the waste material to the dump
Table 3: Effects related to the objectives

<table>
<thead>
<tr>
<th>Objective</th>
<th>Total of the pathway: release of waste material to the dump</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimise financial costs</td>
<td>Costs</td>
</tr>
<tr>
<td>Minimise environmental damage</td>
<td>Emissions</td>
</tr>
<tr>
<td>Scarce resources (space and materials, etc.)</td>
<td></td>
</tr>
<tr>
<td>Minimise leaching out of hazardous compounds</td>
<td>Emissions (leaching out from the waste material)</td>
</tr>
<tr>
<td></td>
<td>Control the exposure</td>
</tr>
<tr>
<td></td>
<td>Reduce pollution</td>
</tr>
</tbody>
</table>

The system will clarify the facts and values at stake and supports decision-makers by given attributes to ‘calculate’ and compare the costs, environmental damage and leaching out of hazardous compounds. The decision support system thereby rises to the challenge of integrated waste management.

Conclusions and discussion

At the end of this paper, we will draw some conclusions from the previous two cases and the presented theory about the developing process and use of DSS in environmental problems.

DSS may be a useful tool in integrated problems. If multiple perspectives are present, like costs and environmental aspects, the decision-makers stand for a complex problem. Moreover, DSS becomes valuable when a field of actors with different interests is involved. So, in complex problems with a complex decision context DSS may be used to simplify the decision process.

Therefor, a proper development of the DSS is necessary. The method here presented is to separate facts from values. Analysing the cause/effect chain gives information about the facts at stake. The facts are related to values by means of fundamental objectives.

A result of the separation of facts from values is that the subjectivity of the decision-maker may stay relevant. So, the DSS does not make the decision. The decision-makers are supported, but will not be replaced by the DSS. Furthermore, a proper use of DSS needs a balance between simplicity and complexity. The developer of a DSS intends to simplify the decision process, but must be aware of losing important information. The use of DSS in the cases above is further characterised by highlighting the environmental aspects of the decision problem, because these aspects are often not transparent in the decision problem.

DSS gives a generic framework for decision support; this contrasts with some technology assessment methodologies, which are related to one special case. For a generic framework an important issue is the applicability of the framework for a special case, because in some cases the framework will fail to support the stakeholders and even sometimes give wrong or ill information. So it is necessary to work in a reflective way with DSS, which of course is not unique for DSS.

Literature


Tuijn, J. van, ‘VROM is om: immobiliseren is weer bespreekbaar’, In: Milieumarkt, 7e-jarigang, nr.6, p.18-21, 1993.