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A

Facilitated Workshop

A Participatory Method for Planning of Countermeasures in Case of a Nuclear Accident

K. Sinkko, M. Ammann, R.P. Hämäläinen, J. Mustajoki

Säteilyturvakeskus
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Abstract

This report describes the participatory facilitated workshop method and its use in nuclear emergency preparedness planning and management. The aim is to give guidance to responsible organizations on how to arrange such a workshop. The facilitated workshop is a group process that utilizes multi-criteria decision analysis to discuss the participants' concerns and issues, and ultimately to decide on a course of action. The objectives are to achieve a mutual understanding of the issues at hand and a united commitment to the action to be implemented. The facilitated workshop method seems to fit well both in the beforehand planning of early protective actions and in the planning of countermeasures in the later phase of an accident. In beforehand planning, it can also be seen as an in-depth training method for the participating authorities.

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Avainsanat: ydinonnettomuustilanteiden hallinta, suojaustoiminta, moniattribuuttipäätösanalyysi, sidosryhmien osallistuminen

Tiivistelmä

Tämä raportti esittelee päätösriihimenetelmän, jota voidaan käyttää ydinonnettomuuksien hallinnassa ja niihin varautumisessa. Raportin tavoite on kertoa viranomaisille, miten päätösriihi parhaiten järjestetään ja mitä sen suunnittelussa pitäisi ottaa huomioon. Päätösanalyysiteoriaan perustuva päätösriihimenetelmä toimii hyvin, kun päätöksiä on valmistelemassa useita eri sidosryhmiä. Se on menetelmä, jonka avulla voidaan ottaa huomioon kaikkien päätöksentekoon osallistuvien sidosryhmien näkökohdat tasapuolisesti ja avoimesti. Se luo viitekehyksen, jonka avulla päätösongelmasta voidaan keskustella rakentavasti ja päätöksen taustoja viestittää muille. Näin ollen päätösriihi on höydyllinen menetelmä ydinonnettomuuksien hallinnassa ja erityisesti niihin varautumisessa.

Contents

1 Introduction

Justification and optimization of countermeasures are the basic principles in radiation protection as is emphasized by international organizations (ICRP to appear; OECD/NEA 2002). Countermeasures should be implemented so that more good is achieved than harm, and to maximize the net benefit. These organizations also advocate that the decision making process on countermeasures must be open and transparent to the public, and that all relevant attributes – both scientific facts and social factors – should be considered in a rational manner. They have also recognized the importance of national beforehand planning in order to take into account country and site-specific factors.

Openness, transparency and participation by all the relevant stakeholders are all important factors for a balanced and sustainable decision making on public issues (Renn et al. 1995; Susskind and Field 1996). Beierle and Cayford (2002) have argued that a managerial model, where the decision is made by authorities, does not suit environmental decision making problems, and that consensus-based participation is needed to account for the public interest. In this respect, planning in advance is essential to identify all the relevant stakeholders and potential problems that may occur in a real accident situation.

The stakeholders or interest groups are the key players that share the decision. These include national and local authorities, expert organizations, industry, producers and also the public. They can be engaged in the decision making process in various ways (see e.g. Mumpower 2001; Rowe and Frewer 2005). Current practices range from those where interested parties are merely informed about the decision to those where the public makes the decision based on a recommendation (McDaniels et al. 1999). The most applicable citizen participation models include advisory committees, planning cells, citizen juries, consensus conferences, negotiated rulemaking, facilitated mediation and deliberative opinion polls (Renn et al. 1995; Beierle and Cayford 2002; Rowe and Frewer 2005). Participation should not, however, replace modern forms of representative democracy but it should be an integral part of the decision making process (Renn et al. 1995).

Individual participation methods have different and apparent advantages but no single method is applicable in all situations. Some of the methods are also prone to shortcomings that have led to criticism (Gregory et al. 1993; McDaniels et al. 1999; Renn et al. 1995). For example, the decision might not be accountable or feasible, and long-term planning might be neglected if the participants are not responsible for the implementation of the decided actions. The focus might be in the public involvement itself, rather than being a means to the results (Rowe and Frewer 2000). The working procedures and efficiency in the use of time in the group meetings can also be poor (Hämäläinen and Leikola 1995; Susskind and Field 1996). Communication can also be unstructured and the information not in the form needed in the decision making process. The reported experiences emphasize the importance of having relevant information, and clear procedures and methods for the decision making process (Sinkko et al. 2004). This need can be met with participatory methods that articulate the factors and judgments systematically and openly for all the people concerned.

This report describes the facilitated workshop method and how it can be applied in planning of protective actions in a case of a nuclear accident. It is a participatory approach which aims to include the concerns of all key players openly and equally in the decision. The approach employs a group process where responsibility is placed on the participants to assimilate information and to provide judgments. The main characteristic difference compared to other methods is that it has a clear structure based on decision analysis offering a scientific regime to assess intervention levels that are justified and optimized.

Multi-criteria decision analysis (MCDA) provides a suitable framework to deal with complex decision making problems with multiple attributes and alternatives (see e.g. Belton and Stewart 2002). Thus, it suits well the facilitated workshops. It helps to clarify the objectives (e.g. ‘avoid radiation-induced cancer cases’, ‘reassure the public’) and to identify the attributes that can be used to measure the success of a strategy in achieving the objectives (‘radiation dose’, ‘subjective score of reassurance’). The aim is to enhance understanding of the problem, to communicate preferences, values and objectives, and to guide the decision makers or stakeholders in their choice of the most preferred action. The approach provides a set of techniques to model the decision makers’ preferences. It is also possible to incorporate uncertainties and risk attitudes in the decision. All in all, MCDA is a learning process that generates insight into the decision problem, and it does not automatically provide a problem solution.

The MCDA approach has been applied to various social and environmental decision making problems such as wastewater treatment and wilderness preservation (McDaniels 1996; McDaniels and Roessler 1998; Renn et al. 1995; Gregory and Keeney 1994). Marttunen and Hämäläinen (1995) applied MCDA as an individual interactive computer supported interview method and involved a large number of stakeholders in two river development projects. The papers by Apostolakis and Pickett (1998), Hämäläinen (1988, 1990, 1992), Hämäläinen and Karjalainen (1992), Keeney and von Winterfelt (1994), Keeney (1980) and Phillips et al. (2006) are examples of case studies that deal with the clean-up of a hazardous waste site, nuclear energy policy and management of nuclear waste. In the field of nuclear emergency management, MCDA has been applied and facilitated workshops have been organized in various countries (Albrecht et al.

1997; Aumonier and French 1992; Bartzis et al. 1999; French et al. 1993, 1996; International Chernobyl Project 1991; Hämäläinen et al. 1998, 1999; Ammann et al. 2001; Zeevaert et al. 2001; Sinkko et al. 2005; Geldermann et al. to appear).

This report is organized as follows: Section 2 describes the facilitated workshop method and its use in the planning of protective actions in a case of a nuclear accident. A short overview of the main steps of the MCDA process is given in Section 3. Finally, Section 4 discusses the pros and cons of facilitated workshops.

2 Facilitated workshop

A facilitated workshop is an intensive session or working meeting attended by key players with different fields of expertise, or representatives of those who are likely to be affected by the decision (Phillips and Phillips, 1993). Usually the workshop does not have a fixed agenda or prepared presentations. The primary arrangement is a small group of key players seated at a semicircle to discuss the problem, and a facilitator who keeps the discussion focused and goal oriented, and aids in achieving a mutual understanding. Based on the discussion, the views of the group are modeled using a decision-analytical approach and decision-aiding technology. The facilitator is assisted by an analyst, who builds the model and takes notes of the main points of the discussion, of judgments and decisions made etc. It is essential that the participants have eye-to-eye contact. Only full-time participation is allowed; calendars should be cleared and the use of the mobile phones forbidden. Table I presents general guidelines for the workshop.

Table I. General guidelines for a workshop.

- Welcome everyone and thank them for coming to *work* together to achieve the objectives. Introduce the support team and let the participants introduce themselves. Make the participants feel that their knowledge and views are essential.
- Clarify the roles of all participants, facilitator and analysts. Reflect to what extent the stakeholders are adequately represented and the representatives sufficiently competent to achieve the objectives. Discuss who will make the final decision.
- Clarify the objectives of the workshop and the aspired deliverable at the end of the day. In case of emergency, the objective would probably be to agree on a course of action, whereas otherwise the objective could be to induce a learning process to broaden the participants' understanding of all the issues involved and of the actual decision-making process. The deliverable could then be a detailed action plan to be followed in similar cases of emergency.
- Describe the method to be used, and the workshop arrangements and 'rules'.
- Brief the participants about the problem setting to bring them all to the same level of knowledge about the situation.
- Clarify who will use the results of the workshop and to what purpose, and whether the work will be continued. Agree on how the results of the workshop will be published and agree on the level of confidentiality (for example, agree that all persons or organizations will be anonymous).
- At the end of the day, reflect on the workshop and gather feedback from the participants to further improve the workshop method. Finally, thank the participants for their efforts.

2.1 Forms of workshops

Ideally a workshop lasts for two or three days, as such an arrangement offers time to reflect on the case and revise thinking. During the first day, the relative importance of the attributes might be judged, the pros and cons of each option analyzed and a preliminary ranking of the available options obtained. In the first evening, the participants would have a chance to discuss open issues in small groups, digest them over night and come back the next morning with new perspectives (French and Papamichail 2003). The second, and possibly the third, day could be devoted to analyzing the results, further discussing open issues, carrying out sensitivity analyses, and perhaps modifying and re-analyzing the model. Finally, the results of the workshop would be summarized and a decision made on which action to recommend or implement.

Often, it might be difficult to find a convenient time slot for the whole group, and a commitment for two days might not be acceptable for all participants. Therefore, shorter forms of decision conferences have been suggested. For example, in a spontaneous decision conferencing concept, the whole process can be accomplished in just a few hours with minimal arrangements (Hämäläinen and Leikola 1995). Alternatively, the workshop can be arranged during a single working day. This kind of a process can be seen to better fit the demands and restrictions of emergency management.

Yet another approach is the decision analysis interview technique (see e.g. Marttunen and Hämäläinen 1995). It is an analysis of a decision problem from the perspective of one key player at a time. After all the interviews have been made, a common meeting with all the participants is recommended to discuss the different views of the participants and to resolve the disagreements.

In all cases, careful preparations are of paramount importance for a successful workshop. These include agreements on the methods, collection of background information, contact creation and various preparatory meetings. The shorter and more intensive the workshop is the more pre-arrangements are necessary. A preliminary workshop that is attended by a small group of experts has been found useful, especially in preparation of an intensive one-day workshop. In this way, it can be assured that all pertinent information has been collected. It can also be useful to send an information package to the participants prior to the workshop. Annex 1 shows, as examples, the invitation letter and Annex 2 the information package that have been prepared for a workshop dealing with clean-up actions in inhabited areas.

2.2 Phases of a one-day workshop

In a one-day workshop, the agenda of the workshop should be rather specific, as the time frame does not allow much room for improvisation. Several phases can be identified in a workshop. Typically, these include at least (i) introduction to the approach and the case, (ii) structuring of the problem, (iii) elicitation of the preferences, and (iv) analysis of the results. Each of these is expected to last for about an hour and a half.

In the first phase, the facilitator describes the workshop approach and the main steps of the process. The participants are provided with background information, such as basic principles of radiation protection and possible legal issues. The introductory phase ends with briefing the participants on the case at hand. An emergency management expert describes the accident scenario and the pros and cons of protective actions. In addition, he/she may compare the health risk of the accident with other health risks, such as exposure to radon or from past accidents.

In the second phase, the problem is explored and issues of concern are identified, for example, by using the MCDA approach. This approach is described in more detail in Section 3. The goal is to find decision alternatives that are worthwhile investigating in detail and the criteria or attributes that could be used to discriminate between them. The elicitation of attributes can be done for example by using a text editor and projecting key words of the discussion on the wall or by using Post-Its. During the discussion the participants are encouraged to suggest new attributes or to modify and group the given ones. It is a good idea to collaboratively define the attributes in order to create a common understanding of their meaning. The criteria are eventually arranged in form of an attribute or value tree (see Figure 5 of Annex 2). There may be also iterations in this process: attributes may be refined and new decision alternatives may be identified. The facilitator keeps the discussion focused and tries to ensure that all concerns are addressed and the final attribute tree is acceptable to all participants. The outcome of this phase is a computer-based decision model. It comprises the attribute tree, the list of decision alternatives, and a decision table that contains numerical assessments of the attributes of each decision alternative (cf. e.g. Belton and Stewart 2002). Sometimes the consequences of the decision alternatives (i.e. attributes) can not be assessed instantly during the workshop, and a predefined set of decision alternatives has to be used.

In the third phase, the relative importance of attributes is judged, and overall preferences of the decision alternatives are obtained. These can be further investigated with sensitivity analyses. The elicitation of preferences can be carried out jointly with all the participants, or within groups of two or three people representing the same stakeholder group. In the latter case, a wider variety of views can be collected. Each group can have a portable computer to work with their decision model, and the results can be collected through a wireless local area network (WLAN) and a computer acting as a server. In the final phase a conclusion of the analysis is drawn and the further course of actions is decided.

Figure 1 shows the main steps of the decision analysis process. As can be seen from the figure, it is an iterative process, as it is often necessary to go back and revise an earlier stage.

2.3 Workshop participants

The ‘right’ participation is consensual and non-hierarchical (Renn et al. 1995). An ethically sound ‘rule’ about who should participate in a facilitated workshop is that representatives of all those who have an interest (a ‘stake’) in the decision considered should be invited. The set of participants should comprise a representative sample of stakeholders and the affected public so that all views and objectives can be included in the process. Participants might be members of central governmental or local authorities, representatives of expert organizations, industry, producers and representatives of citizens. The selected individuals should be apt candidates for an open, participatory process that relies on such skills as listening, learning and mutual co-operation. Each participant should also be a proper spokesperson of his/her respective interest group, and everyone has an equal right to contribute to the discussion.

Protective actions in a nuclear emergency would influence the population and thus a representative participation of the affected population is important to create a fair and competent decision making process. Therefore, participants should represent broadly the public and the involvement should be done as early as possible, for example, by planning in advance (see e.g. Rowe and Frewer 2000). Suitable representatives could be, for example, members of local organizations and fellowships. Recent research from Beierle and Cayford (2002) has questioned the concern that the public makes bad decisions. Their survey of case studies suggests that people are perfectly capable of improving the quality of decisions, for example, through their knowledge of local circumstances.

There should be preferably no more than about 20 participants in a workshop to keep the discussion intensive and effective. A group of 20 is small enough to allow working towards a consensus on the problem and large enough to represent all views. In addition, all the participants have ample opportunities to express their views and judgments. An optimal group setting encourages people to participate actively in the discussion as speakers and listeners.

It is recommended to send an invitation letter to the participants prior to the workshop (see Annex 1) attached with appropriate information on the event.

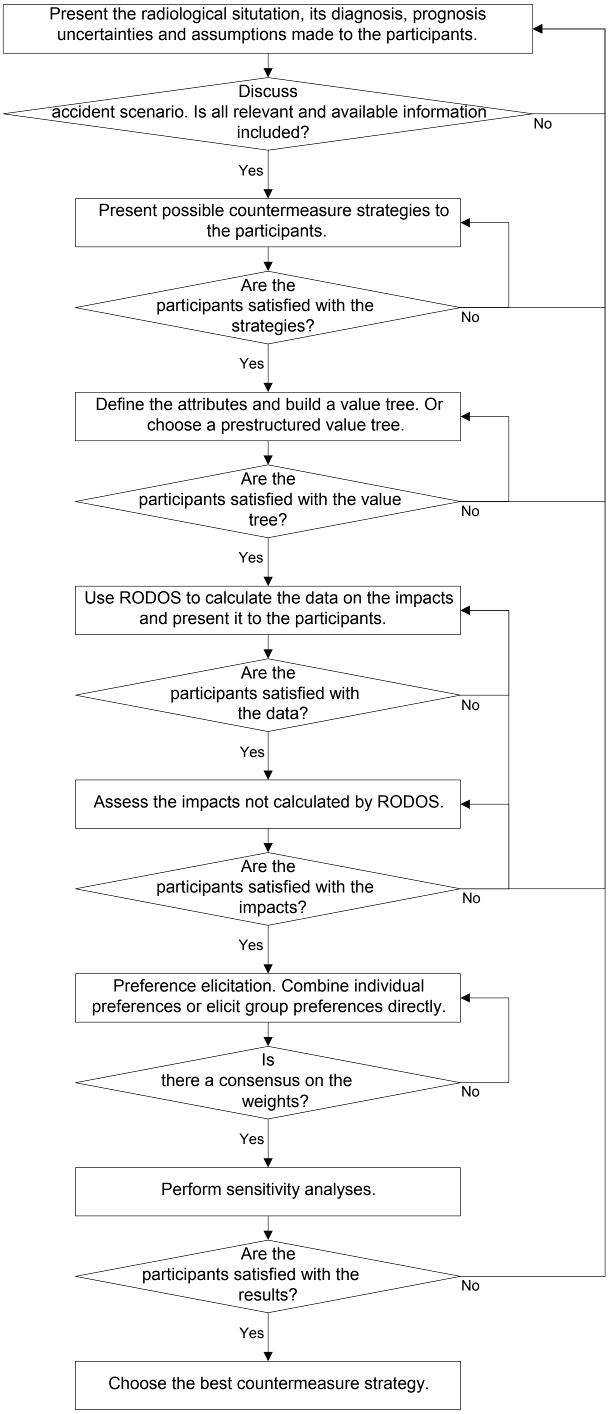

Figure 1. The main steps in the decision analysis. RODOS is a consequence assessment software for nuclear emergency management.

This includes a list of participants, information on practical arrangements and a technical information package describing the problem. Personal contact with each participant is essential before sending the invitation letter, as it helps to motivate the person and allows verifying that he or she is interest in the problem and the method.

Experience has shown that the motivation of the participants is important to the workshop to succeed (Beierle and Cayford 2002). The workshop itself usually keeps the participants motivated as they actively take part in the discussions, share their views and contribute to the decision. The participants experience (or should be made experiencing) that their abilities and skills are important, which might help them better cope with the possible adversities arising the process.

Phillips (1984) has argued that decision conferencing produces conditions for creative and effective decision making when the participants are not on their home ground. Thus, the sessions should take place in conference rooms, or in an especially designed room on the facilitator's premises that is a neutral ground for all the participants.

2.4 Role of the facilitator

The facilitator of a workshop guides and helps neutrally the group to work together to find a solution to the problem. The facilitator is not a stakeholder, chairperson or group leader, and he/she should only concentrate on the process. The content is left to the participants, who share their understanding and are committed to the resolution through providing the content of the discourse, setting objectives and evaluating alternatives (French and Papamichail 2003; see also Seifert's ideas for moderation 2002). The facilitator should raise issues neutrally, come back to open matters, ask simple questions to ensure that all have interpreted the issue in the same way and clarify, or ask the participants to clarify, any jargon which may cause misunderstanding. The facilitator should be experienced in decision analysis and have some knowledge of nuclear emergency management. However, our experience has shown that he/she should come from outside the radiation protection community to be neutral and independent. Yet, one should note that each facilitator has his/her own way of facilitating, and this may affect the action plan devised. For a discussion of different facilitation practices, see Papamichail et al. (2007).

Phillips and Phillips (1993) have made the following list for facilitation:

- one of the main tasks of a facilitator is to see and understand the group life: anger, frustration, emotions, concerns and 'group think';

- a facilitator should not contribute to the content; that would damage his/her integrity as a neutral outsider;
- a facilitator should understand what is going on by summarizing, seeking clarification and asking questions;
- a facilitator should not evaluate the group's work.

In general, the facilitator's role is to keep the discussion focused on the problem at hand and try to prevent the participants from falling in personality-oriented conversation (Ackermann 1996, French and Papamichail 2003). He/she should encourage the participants to express their views and take care that the views of minorities are debated fairly. Possible conflicts should also be calmed down at an early stage of the process.

The decision analysis method might not be understood completely although the facilitator has understandably described the methods and the process to the participants during each step. Therefore, simple examples could be used to clarify each task. There could also be technical assistants available to help the participants if they experience any problems or have questions.

Facilitation is a sensible task where common sense deliberation plays a major role (Renn et al. 1995). Firstly, any facilitation revives disputes and reminds the parties of their conflicts. If opinion differences are realized, participants may tend to escalate the conflict rather than try to resolve it. Secondly, reaching a consensus is not always the most important driving force of individual participants. Some participants may feel (consciously or subconsciously) that their own objectives are more important than the other participants' objectives, or they are more apt 'to prevent their opponents from being better off' and 'to receive more public support or reputation' than to reach a consensus. Furthermore, in discussions people often have a need to protect their social identity and face, and may be troubled with their emotionality, anger, frustration, shame, etc.

In some situations, some participants may question the benefit of using a quantitative model utilizing subjective judgments. In these cases, it could be stressed that mathematical methods are only applied to support the modeling but the main idea of the analysis lies in a clear definition of attributes and action alternatives, in the consequence assessment of actions, and in weighting the relative importance of the consequences. The facilitator can also justify modeling by pointing out that the use of numbers ensures that options and criteria are defined better and that all aspects are considered. In addition, quantification helps to identify areas of critical importance and disagreement. There may also be differences in interpreting the consequences of different options. In this respect, the use of numbers, for example, probabilities 0.6 or 0.8, instead of the wording 'it's likely to happen', can help to better understand other opinions.

2.5 Use of computers and other supporting tools

Computers are typically used during the workshop to carry out numerical calculations and display results graphically and interactively. The simplest setup consists of a single computer used only by the analyst or the facilitator. In this case, the group builds one model that is evaluated together as a group. A more demanding setup is that all participants, or groups of participants representing the same stakeholders, interact themselves with a decision analysis software to elicit preferences on the jointly structured attribute tree. The setup could consist of a separate computer with decision analytical software for each participant (or group or participants) and a local area network to collect and combine the individual decision models. A projector could be used to show the preference models of the individual participants to all others with the aim to communicate their preferences.

Working in groups allows analyzing the stakeholders' preferences separately in each group (Mustajoki et al. 2007). It is important that each participant assesses and clarifies his/her own preferences and can also see and discuss other participants' views. Experience has shown that in most cases participants are able to use evaluation software such as Web-HIPRE (Hämäläinen and Mustajoki 1998; Mustajoki and Hämäläinen 2000) by themselves. A couple of technical assistants are usually sufficient to answer possibly arising questions.

A dedicated web page for the workshop containing information about the case and the methods used was found to be useful. Information can then be displayed on individual screens or projected onto a large screen for all the participants to see. Afterwards, the results of the workshop could be published on the same web page.

Computers powerfully assist the facilitator in his/her tasks and help the participants to deal with differences in opinions. The use of any technology should not, however, dominate or divert the participants from the real issues; nor should it hinder face-to-face contact of the group members.

3 Multi-criteria decision analysis

Decision analysis is a branch of Operations Research, which has its roots in mathematics, economics and psychology. It can be applied to obtain a deeper understanding of a decision problem and all the key players' objectives and values. It helps organizing the available information, incorporating value judgments, and it guides the discussion with the aim to help people make better choices. It also provides a set of techniques to evaluate and rank options according to people's preferences. MCDA, in particular, deals with problems of multiple attributes. The MCDA theory is described in detail in the literature (Keeney and Raiffa 1976; Keeney 1992; von Winterfeldt and Edwards 1986; French 1988; Goodwin and Wright 1992; Hammond et al. 1999; Belton and Stewart 2002). This section briefly explains it and how it can be applied in facilitated workshops on nuclear emergency management.

An essential feature of MCDA is to break down complicated decisions into small and more understandable pieces that can be dealt with individually and then recombined logically. In this way, the relevant objectives and alternative actions can be systematically investigated and insight achieved about the action consequences and value judgments. Additionally, an analytical approach can be helpful in identifying informational needs.

It is recognized that people can benefit from the support and guidance of structured decision analysis. In contrast, in recurrent decisions based on daily experience, it might be simpler, more efficient and more acceptable to decide without recourse to any formal analysis. However, nuclear accidents are very rare and their consequences dissimilar. Therefore, the decision making process cannot be based on daily experience.

Another motivation for the use of MCDA is that when left to their own devices, people easily create and hold on to many kinds of inconsistent beliefs and preferences (Bazermann 2002; Kahneman and Tversky 1982; Spetzler and Staël von Holstein 1975; Gregory et al. 1993). This view is supported by research indicating that the correlation between preference rankings derived from holistic judgment and those derived from decision analyses decreases as the number of attributes in the problem increases (von Winterfeldt and Edwards 1986). Even in the absence of seriously conflicting objectives, unguided intuitive decision making is susceptible to many forms of inconsistency. People's preferences may be dictated by the presentation of a problem and not by its underlying structure, which may lead to irrationality.

3.1 MCDA approaches

Multi-attribute value theory (MAVT) and multi-attribute utility theory (MAUT) (see Keeney and Raiffa 1976) are widely used decision analysis techniques for problems with multiple attributes. They have axiomatic foundations, and they are applicable in facilitated workshops where the purpose is to guide the thinking of the key players, help them to make consistent judgments and to choose rationally. There are also other multi-attribute evaluation methods that could be applied, such as the analytic hierarchy process, fuzzy decision analysis and multi-attribute outranking analysis. For a discussion of these, see, for example, Belton and Stewart (2002).

The consequences of alternative courses of action can rarely be predicted with certainty. For example, the actually released amounts of contaminants are always uncertain. Even if the fallout pattern has been measured, the spatial dose variation can be substantial. MAUT is designed to allow uncertainties and risk attitudes of decision makers to be taken into account. For example, it is possible to use the individual dose instead of the collective dose in the calculations by considering the individual dose distribution. There is also software that makes it possible to incorporate distributions into the analysis (Smith 2002). Incorporation of uncertainties into an analysis, however, requires an understanding of probabilities and – if done in an orthodox way – a series of potentially difficult questions for decision makers.

MAVT does not explicitly take the stakeholders' risk attitude or uncertainties into account but sensitivity analyses can be used to study effects of possible uncertainties in single attributes. Interval approaches (see e.g. Salo and Hämäläinen 1992, 1995) can be applied to study the sensitivity of the result to a variation of several attributes simultaneously (Mustajoki et al. 2006).

Cost benefit analysis (CBA) has also been applied to beforehand planning of protective actions (IAEA 1994; Gjörup et al. 1992). It has its grounds in economic theory. Typically, the analysis provides decision makers with information and it does not require decision makers to express value judgments (French 1988). Therefore, the CBA method is not very applicable in workshops where value judgments are made by the key players. Another apparent difference is that in MAVT the values of attributes are converted into common units, whereas in the CBA, monetary units are used. That is, all effects are translated into financial values regardless of how intangible these might be. CBA does not have natural ways to incorporate uncertainties in the modeling as, for example, MAUT does (French et al. 2005).

3.2 Problem formulation

The first task in the MCDA process is to identify the problem itself, as before being able to make a decision, the decision maker has to realize what the problem actually is. In this phase, it is essential to try to find out all the key characteristics of the problem. The framing of the problem is, however, not always straightforward. A problem that initially seems to be clear and reasonably defined may in a further analysis prove to be a part of a larger entity, and the problem should actually be considered in this larger context.

One should also note that the whole MCDA process is often iterative, and the most innovative ideas are obtained by considering different phases of the process interchangeably. For example, a thorough analysis of various objectives and alternatives may bring up new views that pose the problem in a whole new light. In such cases, the decision maker should go back to the problem definition and reframe the problem according to this new information.

3.3 Objectives and attributes

The identification of objectives that are relevant to the decision problem is also one of the key phases of the process (see e.g. Keeney 1992, 1994). To be more useful and understandable, objectives should be measurable, because in decision analysis numerical scales are used to evaluate how the objectives can be achieved by certain actions. The related numerical variables are typically called attributes. One should, however, note that the terms objective, attribute and criterion are not always used consistently in the literature.

Objectives and attributes are not always evident, and time and effort is needed to specify them clearly and fully. Incomplete specification will often lead to too narrow a focus (Hammond et al. 1999). Objective identification can be facilitated, for example, by reflecting the respects in which the alternative courses of action differ, or by listing the pros and cons of each alternative. It might also be helpful to refer to attribute definitions of similar cases.

An attribute hierarchy, also called a value or attribute tree, can be useful in defining objectives and attributes (Keeney 1992). The overall goal is on the top and it branches into rather general and sometimes vague objectives. These can be divided further into sub-objectives, which become more specific the lower down the tree one goes. The building of the objective hierarchy is continued until all objectives are measurable, operational and easy to assess judgmentally. Keeney and Raiffa (1976) propose the following criteria for examining the applicability of the attributes: completeness, operationality, decomposability, absence of redundancy and minimum size.

International organizations with a mandate in radiation protection have emphasized that the basis for a decision must be understandable and acceptable to the public (ICRP 2000; OECD/NEA 2002). Thus, the reasoning behind the decision of what action to take needs to be clearly explained to everyone concerned. This emphasizes the need to understandably define the possible protective actions and attributes. The aforementioned organizations have listed generic objectives for nuclear emergency management, which include minimizing the radiation dose, physical risks, monetary costs, anxiety and disruption of social life, and maximizing the reassurance produced by the intervention (ICRP 1993, 2000; IAEA 1994). In addition, various case studies have been performed in the recent years which dealt with the decision problem of nuclear emergency management and in which various attribute trees have been adopted (Ammann et al. 2001; Atherton and French 1998; French 1992; French et al. 1993, 1996; Hämäläinen et al. 1998, 1999; Hedemann-Jensen et al. 1996; Morrey and Potter 1994; Sinkko et al. 1994; Sinkko 2004; Sinkko et al. 2005). Based on these publications the following list of attributes is suggested:

Individual dose to the public. Some members of the public might be subject to a relatively high stochastic risk or to a risk of incurring deterministic effects. This risk has to be considered individually and can be measured by the individual dose. It is important to be aware that there is a correlation between the collective and individual doses and hence too much weight would be given on radiation related health effects if both are used in a decision analysis (Sinkko et al. 1994). This attribute can be measured with effective external dose and/or organ dose in normal living conditions and, when an action is taken, integrated over the action period (e.g. sheltering or evacuation time, units in mSv).

Collective dose to the public. The standard assumption within the radiation protection community is that exposure to radiation increases the risk of cancer, regardless of how small the exposure is. If the individual risk is very small, stochastic health effects are still expected when large population groups are exposed. This attribute could be measured as the projected collective dose to the public (manSv). It could also be converted into the expected number of fatal cancer cases or number of cancer incidents in order to be more understandable for persons outside the radiation protection community. Except for thyroid cancers, it can be assumed that roughly half of the cancer cases can be cured, i.e. there are twice as many incidents as fatal cases. This attribute can be estimated with the additional number of cancer cases or collective doses with and without countermeasure options.

Either projected dose or avertable dose can be used in decision analysis. The advantage of the projected dose is the additional information it gives: if it is high it may indicate that an action is warranted. Preferences over values of projected dose could also be taken into account by using concave (saving of a unit of dose is more preferred when doses are low than when doses are high) or convex (saving of a unit of dose is more preferred when doses are high than when doses are low) value functions.

Number of thyroid cancers amongst children. Thyroid cancer deserves special attention because this type of cancer predominantly afflicts children. In addition, thyroid cancer has a latency time of only a few years, is rare and can be easily seen in statistics. Better response to treatment of thyroid cancer is another aspect that supports including it as an own attribute. That is, less than 2% of thyroid cancers prove to be fatal (Demidchik et al. 2006), whereas for all other types of cancer, an average of 50% of cancer cases cause premature death. The risk factor to calculate the number of thyroid cancer cases is 0.01 per Gy for children (NCRP 1985). This attribute can be measured with the thyroid dose in children from intake of radioiodine in normal living conditions and when an action is taken (mGy).

Number of thyroid cancers amongst adults. A separation of the number of thyroid cancer cases into those expected in children and those in adults might be useful. A similar breakdown for other cancer types might also be helpful. This attribute can be measured with the thyroid dose in adults caused by radioiodine in normal living conditions and when an action is taken (mGy).

Dose to the workers. This attribute represents the projected individual dose received by the rescue or clean-up workers that implement, generally outdoors, the protective actions. If large numbers of these workers are exposed to radiation (e.g. during clean-up actions) the increased number of expected fatal cancer cases in the group or their collective dose (manSv) could also be used as an attribute. Dose limits to workers are cut-off values for the attribute, as it must be assured that workers are not exposed to higher doses. This attribute can be measured as the effective dose (mSv) or organ (in particular skin) dose (mGy) that workers receive during work hours.

Statistical non-radiation fatalities. The risk of accidents during or due to protective actions might not be much higher than the risk associated with normal human activities and thus the number of fatalities is largely dependent on the number of people affected by protective actions. It has been concluded that the health risk introduced by stable iodine prophylaxis, prolonged sheltering or evacuation is very low (Aumonier and Morrey 1990). Since there is only sparse information on risks of countermeasures caused by accidents, general statistics might be used as an initial approximation for the risk of e.g. road accidents during evacuation travel. This attribute can be measured as the number of fatalities or reduced life expectancy in the alternatives considered.

In some accident scenarios there might be population groups that have a higher risk of suffering death in the course of implementing the countermeasures. Thus, it might be important to consider these groups separately as some countermeasures might endanger their lives. An obvious example is the evacuation of newborns, elderly people or patients during very bad weather conditions.

Social disruption. An accident, and how the people react to it, poses a severe threat to industry and primary production. Firstly, the accident would cause loss of income, for example, due to direct restrictions in selling products that exceed the maximum permitted concentration or contamination levels. The consumers may also react unpredictably and reject all products that are somehow related to the affected area. Exports may suffer from a total loss of confidence in a certain country's products. All this adds up to a threat posed to producers and employees in industry, and the subsequent loss of their livelihood can cause social disruption. Concern on livelihood and value of the property are also important when inhabited areas are contaminated. Relocation may break down the social network and could be a deeply traumatic experience. On this attribute, the alternatives can be evaluated with direct rating.

Anxiety of the population. Anxiety could be defined as a combination of fear and emotions of sadness, guilt, anger and shame (Izard 1977). The majority of persons living in a contaminated area may show varying degrees of psychological reactions in response to an accident (e.g. miscarriage of unborn children). On the other hand, stress may also be introduced by protective actions. The severity of an accident is likely to be comprehended through the protective measures taken, i.e. the more extensive the measures are, the more severe the accident is experienced, and consequently, the higher the health risk. On this attribute, the alternatives can be evaluated with direct rating.

Reassurance of the population. In the long run, appropriate and reasonable extensive actions may reassure the people living in the affected area. Especially measures that people can implement themselves are most effective in reducing stress. On this attribute, the alternatives can be evaluated with direct rating.

Anxiety of the workers. Emergency actions will cause stress among workers who are implementing them. On this attribute, the alternatives can be evaluated with direct rating.

Environmental issues. Protective actions may remedy or deteriorate the living conditions of flora and fauna. Environmental issues may be related to specific aspects of countermeasures, for example, waste management of clean-up actions may cause environmental damages whereas the clean-up itself may improve the situation. On this attribute, the alternatives can be evaluated with direct rating or with another numerical value, depending on the case.

Social feasibility. Some actions may be seen as inadequate (allow to sell foodstuffs with an activity concentration below intervention levels) or too restrictive (relocation), and such not accepted. People are not ready to follow recommendations which are against their wishes or attitudes. On this attribute, the alternatives can be evaluated with direct rating.

Technical feasibility. Technical feasibility is understood in relation to defined quality or quantity, e.g. tons of clean fodder. This attribute is in many cases a constraint preventing the implementation of an action. Large cities can hardly be evacuated, and sheltering, too, is difficult. In some cases actions may differ in their feasibility, for example, sheltering is more feasible than evacuation in bad weather conditions. On this attribute, the alternatives can be evaluated with direct rating or with another numerical value, depending on the case.

Flexibility of strategies. There may be substantial uncertainties in consequence assessment and therefore it should be possible to modify strategies as more information is available. On this attribute, the alternatives can be evaluated with direct rating.

Monetary costs. This attribute contains the direct and indirect costs of protective actions. Cancer treatment costs, associated loss of GDP, and other costs that are proportional to the number of cancers should not be included in this attribute in order to avoid double counting. This attribute can be measured in a monetary unit.

Political objectives and attributes may be part of the decision making on protective actions but they need to be clearly defined. Politics is by its definition activity directed to social matters – a program or procedure – and it can not be as such a measurable attribute. Politicians and authorities write and maintain political programs and the definition and incorporation of these attributes in the decision making process is their natural task. Political attributes should not be considered on the expert level while preparing recommendations.

3.4 Protective actions to be implemented

One essential stage of emergency management and decision analysis is to identify all feasible alternatives of actions. International organizations have published generic guidance on the most important protective actions, especially those for the early phase (ICRP 1993; IAEA 1994). For planning purposes, protective actions have been listed and categorized into those that restrict people's activities or the use of contaminated food or consumables and into those which prevent radionuclide incorporation in the human environment, food or consumables. A comprehensive list of protective actions for different areas – agriculture, inhabited areas – is collected in EU projects such as FARMING, STRATEGY (*www.strategy-ec.org.uk*) and URBAN (Nisbet and Mercer 2002).

In planning countermeasures for the event of a nuclear accident, protective actions can be further developed by considering the possibility of changing the action's scale, timing and duration. For example, the composition and size of the population group to be protected can be modified. It is useful to iterate between the articulation of attributes and creation of alternatives in order not to end up with a too limited set of alternatives. All feasible actions have to be considered that could be effective in controlling a certain exposure pathway. Also the baseline case (taking no action) has to be included in the analysis. In defining an action, its technical and social feasibility, and national/local circumstances have to be considered (can it be implemented in practice as has been planned).

For a successful implementation of protective actions, the intervention area has to be well defined and easily recognizable by the public. It might be comprised of a set of administrative units, for example municipalities. Hence, the benefits and harm introduced by protective actions has to be aggregated within that area. The timing and duration of the proposed protective actions are, in the early phase, related to the presence of the radioactive plume and, later on, to the contamination levels on the ground or in foodstuffs. It also has to be clearly defined who is affected, what is the action taken, when, where and for how long the action is conducted.

Protective actions will in general be justified if the existing annual effective individual dose is rising towards 100 mSv. This value may be used as a generic reference level for establishing protective actions under nearly any conceivable circumstance (ICRP 2000) and could serve as a constraint in the justification and optimization process performed by the decision analysis.

Radiological countermeasures aim at reducing doses to the affected population, and do not necessarily reduce anxiety or stress. Accidents, however, will also cause negative social and psychological impacts. After the Chernobyl accident it was observed, for example, that psychological health consequences were the most significant when compared with economical and radiological ones (Allen et al. 1996; IAEA 1994). It has been concluded that additional actions are needed to mitigate such social and psychological impacts. These can include, for example, debriefing meetings where the victims of the accident can work through their anxiety by discussions.

3.5 Consequence assessment

Consequences are represented by the values of the attributes, for example, the assessed doses and costs with or without the action taken. Regarding attributes that have identifiable variables representing them, the measurement of the consequences is usually easy. Then, a value function can be used to map the consequences to a commensurable 0–1 score scale. By using linear value functions, the increase of the same amount to a consequence gives an equal increase to the score regardless of the initial consequence. However, this is not always the case, for example, the change in costs from 0 € to 1 000 € may result in a larger decrease in the value than a change from 9 000 € to 10 000 €. In this case, one can use, for example, a concave value function to map the consequences into scores.

With other attributes, such as reassurance and anxiety, it will be more difficult to find appropriate statistics or a variable that can be quantified or expressed on a characteristic scale. In these cases, we can use direct rating techniques, in which the preferences over the consequences of an attribute are expressed on grade scales (see e.g. Keeney and Raiffa 1976). When directly rating an attribute, the most preferred alternative is usually given some fixed score (e.g. 1 or 100) and the least preferred alternative the score of zero. The other alternatives are given scores between these to represent the degree of preference

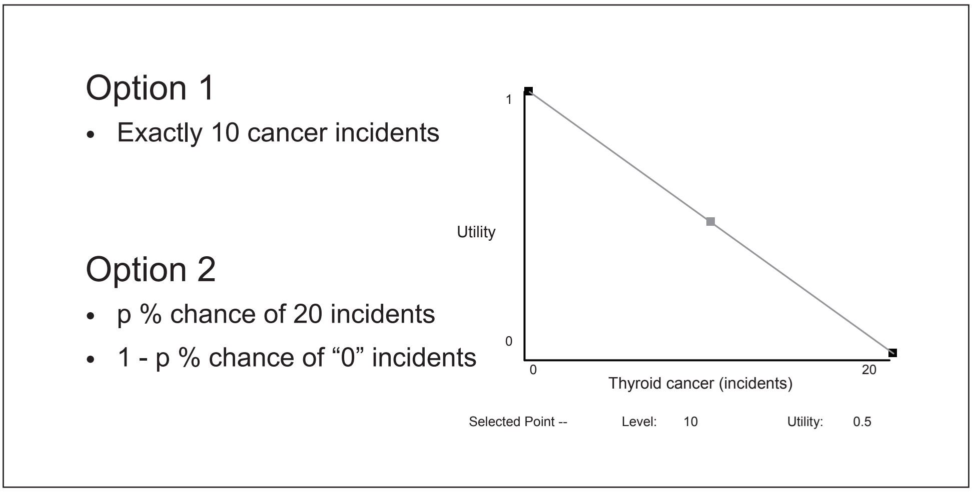

Figure 2. Type of lottery question that can be asked to elicit utility functions i.e. risk attitude.

of this alternative on this attribute. The technique seems to be robust so that numbers do not always need to be precise. The availability of relevant information could be more important than its precision.

Uncertainties and risk attitudes can be included in the consequence assessment by using utility functions instead of value functions. For example, if the decision maker is risk avoiding, the utility functions are concave and the degree of concavity tells how precautionary he/she is. Risk avoiding attitude could be dominating in nuclear emergency management when a population is protected against adverse health effects.

The forms of the utility functions are conventionally assessed using lotteries (see Figure 2). The particular lottery to be offered to the participants when eliciting these utility functions may well leave its mark on their shape. A formulation of the lottery closer to the case at hand would be preferable. For example, if early phase actions are considered, the lottery question could be the following: 'A release is due to happen, but you do not know when. To elicit the utility function you have to assess the probability of the success of evacuation in relation to when exactly you would do the evacuation, e.g., in a small town. You have two options: to shelter and accept 10 cancer incidents for sure or take the risk and evacuate. If you have the people evacuated before the start of the release you avoid almost all cancer incidents. However, if not, you have to accept 20 cancer incidents. What odds do you need as a minimum for deciding on evacuation? Or in other words, what probability of success would make you indifferent between these two options.'

As mentioned above, the incorporation of uncertainties will make the analysis more laborious. There is, however, a way to estimate the influence of uncertainties. Stewart (1995) has found out by performing Monte Carlo calculations that by using expectations of distributions and a simple additive model the correct ranking of actions can be obtained in most situations. The expectations could be well estimated from three or five point approximations to the distributions, i.e. 5%, 50% and 95% fractiles.

All in all, rational decision making requires that the consequences of each action are assessed realistically without overestimation. Conservatism in assessment may cause overestimation of the benefit of an action, an excessive demand on monetary resources, or an increase in stress among the population. Often, the consequences have to be assessed for a specified group of people and integrated over the time the countermeasure is implemented. The required consequences include, for example, the projected individual effective dose that would be received during sheltering or evacuation time, or the number of expected cancer incidents during the next 50 or 70 years and its reduction by clean-up actions.

The aim of the protection strategy in a case of a radiological accident is, first of all, to do everything possible to avoid deterministic health effects (e.g. death or vomiting) in the affected population. The severity of deterministic health effects is related to the dose, and there is a threshold below which no such effects are expected. Just below the threshold for deterministic effects, the stochastic health risk (i.e. cancer) might be unacceptable high. The projected individual dose accumulated in the first hours or in a day (during the plume passage) is of special interest since it is a relevant quantity for expressing the risk of deterministic health effects or high stochastic risk. Stochastic health effects, on the other hand, may be induced by any dose, and only the likelihood of occurrence is growing with the dose, not the severity. From a radiological point of view, it is important that the aversion of stochastic health effects in the population by optimizing protective actions is performed so that the net benefit is achieved and that it is as big as possible.

A straightforward application of the individual dose (or dose rate) as a consequence has turned out to be difficult. The individual dose is normally calculated in different points of intervention area. The average individual dose within, e.g., a municipality might not exceed intervention levels although the individual dose might do so at several locations within that municipality. Therefore, it would be better to use the individual dose distribution, e.g. three point estimates, which however require extra assessments and explanations to key players.

There are different consequence assessment tools for nuclear emergency management, for example: ARGOS (*www.pdc.dk/nucsystems-uk/*), COCO-1

(Haywood et al. 1991), OECD/NEA (2000), RODOS (Ehrhardt and Weis 2000) and WSPEEDI (Chino et al. 2000). These tools can be used to assess, present and predict mainly the radiological consequences of an accident and possible intervention actions (some also assess the monetary costs). They do not allow, however, to calculate all the consequences needed in the decision making process. In addition, general purpose software can be utilized in consequence assessment, for example, GIS (Geographic Information Systems) and spreadsheets together with statistical and production information.

3.6 Trade-offs

In all decisions – whether explicit or not – attributes have to be balanced. In decision analysis, the attributes are assigned weights that can be seen to reflect the trade-offs between the attributes. For example, how much is the society ready to invest to avoid a certain dose? The weights can be given directly, or a specific weighting method can be used (see e.g. Belton and Stewart 2002).

The preference of an attribute over another depends on the range of values they have. For example, the trade-off between cost and number of cancer cases will certainly be different if the choice is to be made among strategies that avert up to 100 cancer cases at the cost of up to 1 million € in comparison to a choice of averting up to 1 cancer case at a cost of up to 100 million €. It is likely that in the first example the attribute cost is not given much weight, whereas in the second, it is. A thorough assessment of trade-offs is essential for good decision making but it is not always an easy matter and prone to mistakes (Keeney and Raiffa 1976; Keeney 2002).

The trade-offs are subjective judgments. There are no universal weights as they all relate to a specific decision problem. In addition, they change according to opinions and are dependent on the resources of a society. There are methods that help to estimate trade-off values and studies that shed more light and understanding on this issue, for example, studies on willingness to pay and the costs of life-saving interventions (Bengsson and Moberg 1993; Katona et al. 2003; Ramsberg and Sjöberg 1997, Tengs et al. 1995). These studies report variations over 11 orders of magnitude for the weight of cost in relation to health benefits with a median of 20 000–40 000 US$ per statistical life saved per year. Tengs et al. (1995) has concluded that more lives could have been saved by shifting resources between life-saving interventions.

However, methods, such as studies on willingness to pay and contingent valuation, which are carried out in decision problems to prevent harm, have been criticized. The problem with contingent valuation techniques is that ‘they capture attitudinal intentions rather than behavior, important information is omitted from questionnaires and their results are susceptible to influence from cognitive and contextual biases' (Gregory et al. 1993). The results of willingness-to-pay studies are no more useful because case studies are usually poorly structured and do not indicate the multidimensional values behind decisions. Values are multidimensional and people have strong feelings and beliefs about these values, which typically are not numerically quantified and are not expressed in monetary terms. Careful structuring of the problem is necessary to identify the underlying multidimensional values, attitudes to risk and trade-offs related to the problem. These are created during the elicitation process in decision analysis. Therefore, it does not seem reasonable to assess trade-off values using problem independent studies. Indeed, a proposal has been made to adopt the multi-attribute value/utility theory in contingent valuation studies (Gregory et al. 1993).

3.7 Analysis of the results

As a result, the MCDA process gives the overall scores of the strategy alternatives for the group or for each interest group. These describe the overall preferences over the alternatives, and are typically analyzed together by projecting them one by one on the screen and discussing them jointly. For each model, the facilitator points out its essential characteristics in order to achieve an understanding of the concept and the preferences of this group. The contribution of the different attributes is studied by breaking down the overall scores into corresponding components.

One should note that the obtained overall values are not the ultimate solution to the problem, but they should be used as a starting point for the further discussion of the strategy alternative to be implemented. The aim of the values is to describe the preferences of the stakeholders in a common framework and by analyzing them to increase understanding of the views of the other stakeholders. The given preference and consequence values may not be accurate, but only estimates for the true values. The sensitivity of the result to imprecision in the model variables can be studied with sensitivity analyses. For example, a single parameter sensitivity analysis is carried out to study the changes in the overall scores with respect to variations on the ratings and weights.

To ensure that the model reflects the views of the participants, they could be asked whether the resulting overall preferences of actions correspond to their holistic expectations (Mustajoki et al. 2007). A positive reply is likely to ensure that the model captures their views; if this is not the case, there might be misunderstandings or biases in the elicitation or the process has changed the thinking of the participants.

4 Discussion

In nuclear emergency management, it is important that all relevant parties deliberate together on countermeasures and that protective actions are planned in advance. There are different planning methods, which range from managerial methods to participatory decision making methods. The managerial method is commonly seen more applicable in the early phase of a nuclear emergency situation, i.e. when emergency management teams make recommendations based on emergency plans. Unfortunately, many times authorities make these plans with only little stakeholder or public involvement.

A joint meeting of authorities and experts is a common way to collect information and to prepare emergency plans. Although generic countermeasures might be advised, such advice is problematic as protective actions cannot be justified and optimized in depth without reference to a particular case (i.e. the actual protective actions and their ranking depend on the problem at hand). Case studies, when planned in a truthful way, are useful to reveal many practical problems and needs for further information. Their findings could be a valuable input to international recommendations, too. The case study method has also proven to be very educating for the planning team and the participants.

A facilitated workshop is a participatory method aiming to include the concerns of all key players openly and equally in the decisions taken. With a proper process of participation, the method can incorporate public values into decisions, improve the quality of decisions through local knowledge, resolve conflicts among competing interests, build trust in institutions, and educate and inform the public. In addition, it can also improve risk communication and understanding of risks. Deliberation and the intensity of the process are features that increase the possibilities of the facilitated workshop to be successful. The facilitated workshop method has been found to be a very applicable method in solving environmental decision problems.

The consequence spectrum of nuclear and radiological accidents is likely to be wide and will depend substantially on the event, nuclide composition of the release, and on the season. This diversity implies that a large number of accident situations need to be analyzed to gain a comprehensive picture of the nuclear emergency management process, and to derive intervention levels for various protective actions. However, recent workshops arranged in various European countries have revealed a lot of similarities. For example, the attribute trees elicited in these workshops were quite similar (EVATECH 2007). The weights of the attributes varied depending on the contamination level given in the accident scenario but when the contamination level was alike attributes were of comparable importance. Thus understanding of countermeasures could be increased and intervention levels elicited by a limited number of case studies and facilitated workshops. Considering the limited resources available and the needs of emergency management it could be a good idea to replace some conventional exercises with facilitated workshops.

Facilitation is a very demanding process and requires competence and personal skill. It would be beneficial to create a European network of trained and skilful facilitators. Ideally they would be capable of facilitating different types of environmental problems and not just nuclear emergency ones. The network could be a forum for knowledge sharing and a basis to respond to today's demands for participatory decision making process. The decision making process in environmental problems is changing more and more from the managerial form towards the participatory form where all stakeholders, including the affected population, are involved. The responsible organizations also have to increase their knowledge in participatory methods to be able to respond to today's demands and to be better prepared for any future accident. In addition, the arrangement of facilitated workshops creates a network of stakeholders, and trains and educates participants in nuclear emergency management.

It is also important to learn in which phase of the process facilitated workshops fit in. Our experience supports the view that facilitated workshops fit well especially into the planning phase where key players with expertise in different areas evaluate the options that are given to the eventual decision makers for a final debate. It is well known that higher level officials desire advice both on what are the alternative courses of action and on the grounds for making a decision. It has not yet been tested whether the protective action strategies, which were analyzed in the different workshops so far, are already appropriate to be given to the eventual decision makers for their evaluation. Nevertheless, the work done by Hämäläinen (1988) encourage preparing advice in a workshop before the problem is given, for example, to the parliament for its evaluation.

The facilitated workshop method can be very successful in improving the quality of decision making and resolving conflicts among competing interests of key players. The danger is that the participation of too small a group tends to narrow down the incorporation of public values in the decision and the education and information of the public (Rowe and Frewer 2000; Beierle and Cayford 2002). Attention should be paid to the responsibility of the participants to communicate to those whose spokesmen they are. In order to allow wider public participation, all relevant material and preliminary results of the analysis could be made available on the Internet for comments, possibly at the same time as it is distributed to the participants.

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ANNEX 1: INVITATION LETTER

This invitation letter template was worked out by Simon French for the purpose of the EVATECH workshop.

<to be written as an official letter of your organization>

<addressee>

Re: EVATECH workshop <date>, <times> and <location>

Dear <addressee>

We are delighted that you have agreed to participate in the that we are holding shortly. Your contribution will, we are sure, help us towards a successful conclusion. EVATECH is a project in the EU's 5th Research Framework Programme. EVATECH is seeking to understand the nuclear emergency management process across Europe and the information and decision support needs of the decision makers therein. As part of EVATECH we are running a series of workshops in several countries to understand the needs of decision makers a few days after a radioactive release from a nuclear accident when considering the choice and implementation of early restoration actions in inhabited areas. In particular, we are running a workshop on <date> from <start time> to <finish time> at <location>. The objectives for the workshop are:

- To identify and verify the factors driving decision making in a radiological emergency situation
- To explore the information needs of all parties involved in decision making workshop
- To identify the forms of strategy that relevant organizations wish to consider

To prepare the national report on countermeasures found to be the most appropriate in our circumstances and in the studied accident scenario. The scenario to be explored will be prepared in advance and a few days beforehand you will be sent a description of the hypothetical events leading up to the issues to be discussed in the workshop. The workshop will be facilitated by <facilitator> who will help us focus on the choice of restoration strategies and on the evaluation of options. However, the workshop's format is far from fixed and you should come prepared to contribute your ideas and inputs freely. Do not prepare any data or analyses beforehand. We shall not need to venture into any great detail. We intend to gain a broad overview of the issues and perceptions that will drive decision making on restoration in urban areas. Please clear your diary fully for the workshop. In order to focus on the issues and build a shared perspective between the participants, it is important that all attend for the full discussion. Our intention is that all of us may discuss the issues without disruption and outside distraction. There will be coffee breaks etc. to make any essential phone calls, but we ask that you do not take calls during the meeting. Please let us know if you have any special dietary requirements. The output of the meeting will be confidential until there is broad agreement on the conclusions and the wording of the report. No statements will be attributed to any person in the meeting. The findings will be made available to the EVATECH consortium and, again if there is broad agreement, more widely. We attach a list of those, who like yourself, have agreed to participate. Attached is a map showing <location> and suggesting transport links. <you may wish to remark on any transport issues such as 'allow at least ??? min to get from X to Y', or trains times may be found at www.???.???> <Accommodation issues if relevant>

Before the workshop we invite you also to a short introductory meeting on <date> from <start time> to <finish time> at <location>. In that meeting the participants of the workshop will be exposed more closely to the objectives and working procedures of the workshop. Do contact us if you have any questions or concerns about the introductory meeting and/or the workshop or about the EVATECH project.

We look forward to seeing you on <date> at <location>.

Yours sincerely

<Name(s) and affiliation(s)>

Attachments:
Institutes or individuals participating
Map, etc.

ANNEX 2: INFORMATION PACKAGE

Introduction

As a consequence of a major nuclear accident, thousands of square kilometers may be unevenly contaminated by radioactive fallout, and various protective actions might be needed to reduce the dose to the public from the deposited radionuclides. In inhabited areas, a broad range of surfaces is contaminated by the radioactive fallout: exteriors and interiors of buildings, streets, trees, bushes and lawns in parks and gardens. The contamination level varies depending on the release composition, prevailing weather at the time of the fallout, and on the surface. Precipitation causes generally higher total deposition. Dry deposition contaminates predominately roofs, streets, leaves of trees, bushes and lawns. Rain washes these surfaces and contaminants accumulate on the ground and in the sewage system. In addition to deliberate decontamination, regular cleaning and natural processes, such as precipitation, transport contaminants from building surfaces to the topsoil, and from the topsoil into the deeper layers. Such processes together with the radioactive decay will reduce the dose-rate in the course of time.

From the radiation protection point of view, the aim of protective actions is to reduce the individual as well as the collective dose to the public and at the same time not to unduly incur dose to workers carrying out the recovery operations. It is also desired to reduce radiological impacts on the environment, to bring the contamination under control, and to keep the area in or return it back into unrestricted use by feasible decontamination measures.

A comprehensive overview of the major methods to clean-up large areas is available in the literature (Andersson 1996, Andersson and Roed 1999, Andersson et al. 1995 and 2003, Brown et al. 1996, IAEA 1989, Lehto 1994). The successful implementation of clean-up actions, however, requires adequate knowledge of the situation, careful planning in advance, and the involvement of all stakeholders.

A facilitated workshop provides a suitable forum for identifying those issues that the stakeholders and the population of the contaminated areas care about. It employs a group process where responsibility is placed on participants to assimilate the information and to provide judgments. Decision analytical methods are applied in the workshop to define the objectives of clean-up, to identify the criteria or performance measures that distinguish between different alternative courses of actions, and to assess their relative importance to the decision. The aim is to create better decision alternatives and a structured overall view of the problem.

The workshop is assumed to be organized about a week after a hypothetical accident. The task of the workshop is to evaluate clean-up actions and to reconsider evacuation. The focus is on those actions which could and should be taken during the first two or three weeks after the accident in order to be effective.

Accident scenario

It is assumed that a hypothetical core-damaging and containment leak accident[1] had occurred a week ago at the Loviisa NPP, and that this has led to the contamination of the eastern part of the Uusimaa province. The assumed time of the accident is in the beginning of June, on a working day. The progress of the accident was described as follows (Niemelä 2002):

'The accident starts with a fire in one of the electrical cabinet rooms causing a successful shutdown of the reactor. An independent failure of the emergency core cooling system and the effects of the fire prevent core cooling. Containment is successfully isolated. Core heat-up starts 3.5 hours after shutdown and one hour later the vessel breaches at high pressure. Containment sprays start and operate successfully. The debris in the cavity cannot be cooled, however, and its temperature reaches 2 500K seven hours after shutdown. Five hours later, the temperature has stabilized at 1 600K. Large quantities of hydrogen and carbon monoxide are generated. Combustion occurs 43 hours after shutdown and causes the containment to fail. As a consequence, radionuclides escape to the environment.'

The release began 43 hours after the shutdown, at 08:00, and lasted for 12 hours. The release rate was not constant as the initial intense release went down roughly exponentially in 12 hours. The effective release height was 100 m, which corresponded roughly to an initial sensible-heat release rate of a few megawatts (the leak was at a height of 60 m). Based on measurements it was concluded that the fallout could be explained by the release fractions given in Table I.

The accident day (first day) was a rainless day over Finland with weak winds (4–9 m/s) from south and southwest. The wind turned during the second night and started to blow from south and the southeast. There were sporadic rain showers during the night and in the morning hours on the next day. Thereafter the weather was dry again.

The site of the hypothetical accident is situated 90 km east from the capital area of Finland and 10 km southeast from Loviisa town. There are 7 600 inhabitants in Loviisa and over one million inhabitants in the whole fallout area (Table II, Figure 2).

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[1] The estimated probability of occurrence of such a containment failure accident leading to a significant release is less than one in 100,000 per reactor-year for this NPP.

Table I. Release fractions used in consequence calculations.

Nuclide group	Release fraction
Noble gases	$8 \cdot 10^{-1}$
Iodine total	$1.1 \cdot 10^{-2}$
Alkaline-group (Cs, Rb)	$1 \cdot 10^{-2}$
Tellurium-group (Te, Se, Sb)	$1 \cdot 10^{-6}$
Alkaline earth-group (Sr, Ba)	$<1 \cdot 10^{-10}$
Ruthenium-group (Ru, Mo, Tc)	$<1 \cdot 10^{-10}$
Lanthanide-group (La, Nb, Zr, Cm, Ce, Nd, Pm, Sm, Eu, Pu,refr. Ox. Nb, Zr)	$<1 \cdot 10^{-10}$

Table II. Municipalities in the fallout area and the number of inhabitants.

Artjärvi	1 570	Kerava	30 482	Pernaja	3 783
Askola	4 421	Kärkölä	4 978	Pornainen	4 186
Espoo	216 836	Lapinjärvi	2 995	Porvoo	45 403
Hausjärvi	8 173	Liljendal	1 464	Pukkila	1 936
Helsinki	559 718	Loviisa	7 498	Riihimäki	26 268
Hyvinkää	42 736	Myrskylä	1 974	Ruotsinpyhtää	2 967
Iitti	7 415	Mäntsälä	16 908	Sipoo	17 760
Järvenpää	36 380	Nurmijärvi	34 029	Tuusula	32 915
Kauniainen	8 543	Orimattila	14 202	Vantaa	179 856

The emergency management team of the first day decided to evacuate Loviisa and the eastern part of Pernaja. In addition, it recommended sheltering during the passage of the plume and intake of stable iodine tablets prior to it in the following municipalities: Ruotsinpyhtää, Lapinjärvi, Liljendal and in the western part of Pernaja (Figure 1).

Consequence assessment

It is assumed that the caesium concentration on the ground was measured during the first week and the fallout area could be mapped. Some measurements on the efficiency of the clean-up actions were also performed. Nevertheless, dose assessments are still believed not to be more accurate than by a factor of 2 or 3.

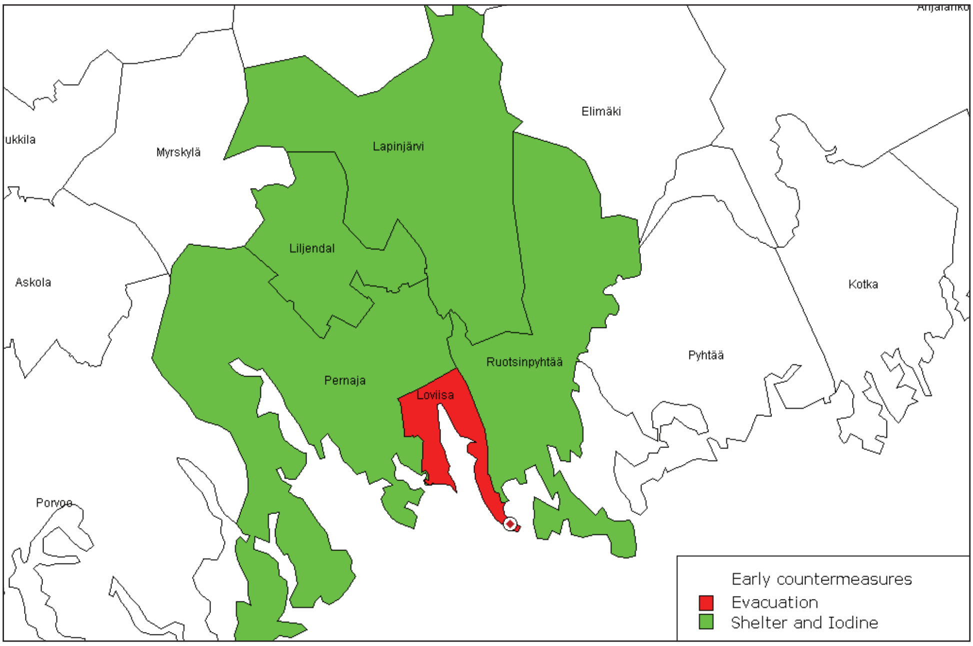

Figure 1. To protect the population evacuation, iodine prophylaxis and sheltering was recommended and implemented before the release in the marked municipalities.

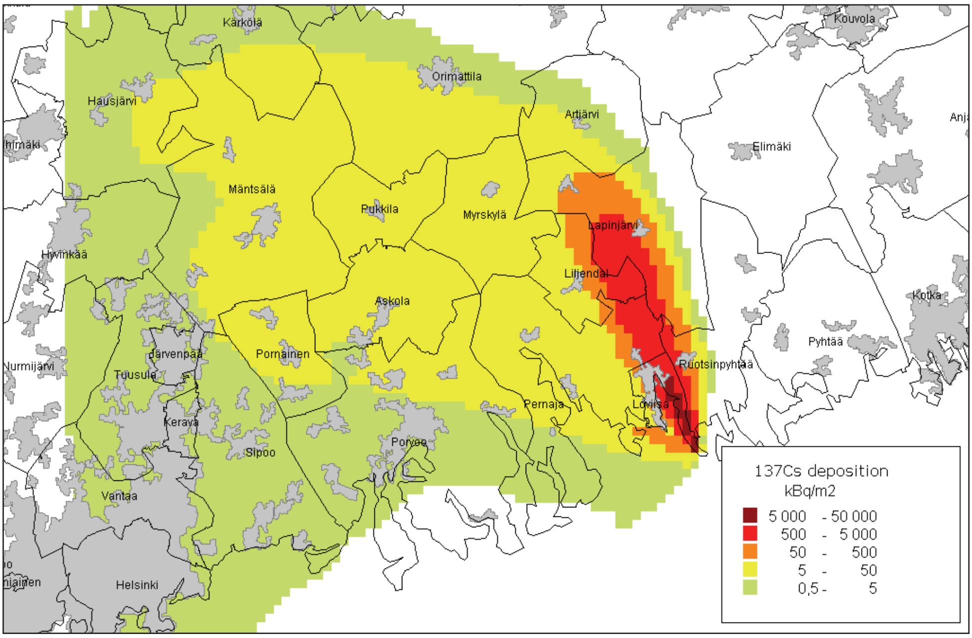

Figure 2. Caesium deposition, affected municipalities and population centers (grey areas).

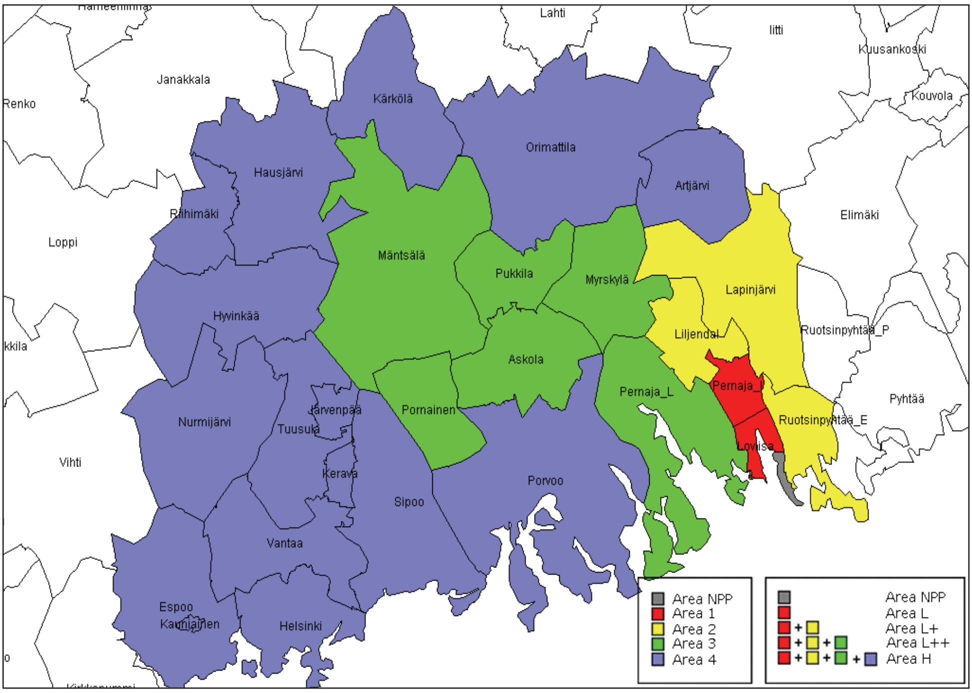

Figure 3. Subdivision of the fallout area for consequence assessment.

Table III. Key figures for the five areas and the consequence assessment if no actions are taken.

	Area NPP	Area 1	Area 2	Area 3	Area 4
Number of population	28	8 429	6 070	29 600	1 101 614
Number of houses	25	2 191	2 487	10 845	14 4025
^{137}Cs fallout (kBq/m^2)	7 423	1 145	273	8	2
Dose in days 1 – 7 (mSv)	19	3	1	0	0
Dose in days 7 – 30 (mSv)	36	5	1	0	0
Dose in days 7 – 365 (mSv)	287	44	11	0	0
70-year dose (mSv)	2 263	213	73	2	0
Collective dose, 70 y (manSv)	63	1 797	440	67	283
Increased cancer cases	6	180	44	7	28

There was rain in Loviisa, Liljendal, Lapinjärvi, Pernaja and Ruotsinpyhtää during the plume passage, which caused wet deposition in parts of these municipalities (over 50 kBq/m^2). Close to the nuclear power plant the measured fallout is over 5 000 kBq/m^2. Elsewhere up to Mäntsälä the fallout is 5–50 kBq/m^2 and a decade lower in the capital area of Finland.

The ^{134}Cs fallout is equal in magnitude to the one from ^{137}Cs, and the deposition of ^{131}I is ten times higher. In this scenario the lifetime dose is mainly caused by caesium isotopes and only a few percents are caused by iodine. The dose rate is high during the first week after the accident as a result of the iodine fallout. This has to be taken into account when planning clean-up actions.

For the purpose of analyzing clean-up actions, the major fallout area has been subdivided into five areas (Area NPP and Areas 1 to 4 in Figure 3) according to the caesium fallout but taking into account demographic and administrative features. With the exception of the municipalities of Loviisa, Pernaja and Ruotsinpyhtää (which have been divided so that the dividing line passed through sparsely populated areas), the subdivision is made along the municipality borders. Table III gives an assessment of the consequence within these areas if no clean-up actions are performed.

Area NPP is the most contaminated area but it has only 28 inhabitants (Figure 4). The ^{137}Cs fallout is more than 5 000 kBq/m^2 in that area and the dose rate caused by the fallout is 0.6 mSv/h in the first hours after the plume passage. The estimated 70-year dose is over 2 000 mSv.

Area 1 consists of Loviisa town and the eastern part of the municipality of Pernaja. The average ^{137}Cs fallout is 1 000 kBq/m^2 in that area. The NPP and Loviisa were evacuated prior to the release and the inhabitants of Pernaja were recommended to take iodine tablets and to shelter indoors during the plume passage. If the inhabitants of Loviisa returned to their homes one week after their evacuation they would receive a dose of 5 mSv by the end of June and 213 mSv in 70 years. These figures might be put into perspective by comparing them to the dose that the inhabitants of that area receive from the inhalation of radon, which is estimated to be 7 mSv in one year and 500 mSv in 70 years.

Area 2 encompasses Liljendal, Lapinjärvi and the southern part of Ruotsinpyhtää. The fallout is very uneven in these municipalities and the estimated population weighted average is 270 kBq/m^2. The inhabitants were recommended to take iodine tablets and to shelter indoors during the plume passage.

There was no rain in other areas during the plume passage and the ^{137}Cs fallout ranged between 5 and 50 kBq/m^2 in Area 3, and between 0.5 and 5 in Area 4, respectively.

The release has contaminated various surfaces of the living environment. To what extent a contaminated surface contributes to the dose depends on various

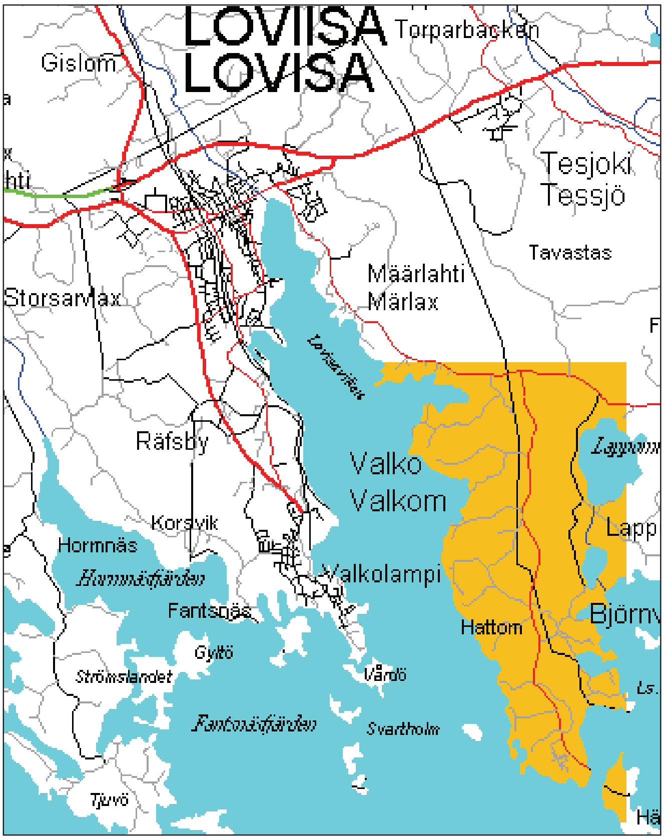

Figure 4. Loviisa town and the Area NPP (marked with ochre).

factors: on the type and composition of the deposition, the time spent in the proximity of such surfaces and the shielding by building material. Assuming normal living conditions, the major contribution to the lifetime dose comes from the soil, about 60–80%, if the fallout contains caesium (Andersson 1996, Brown 1996, Moring and Markkula 1997). In urban downtown environments (office areas), the main contributors to the dose are walls and roofs, 30–60%. Under dry deposition situation, the contribution of walls is about 5–10% and that of roads and pavements about 5%. Roofs contribute to about 10%. Because Finnish buildings are quite air-tight, the lifetime dose from the indoor contamination is negligible if the ventilation is shut down during the plume passage.

If no recovery operations are taken, the contamination remains in the area. The dose rate will, however, decrease in the course of time through natural processes (radioactive decay, weathering, migration to deeper soil layers, wash off, resuspension) and human activities (construction, regular cleaning).

Clean-up techniques

The aim of the workshop is to choose the most appropriate strategy for cleaning up the contaminated inhabited areas. A strategy is an action plan that tells what housing area is cleaned up and by what technique. Also relocation needs to be considered in this action plan.

Requirements for the clean-up actions in this scenario are that they are applicable on a large-scale during summertime and that their early implementation is possible. There are methods which are considered not to be applicable when large areas have to be decontaminated during the first weeks after the accident (e.g. peelable coatings, road planning, skim and burial ploughing and sand blasting). Such techniques were rejected due to their poor effectiveness, high cost or low feasibility.

The following clean-up techniques are selected for further consideration.

Washing of buildings

In general, fire hosing of roofs and walls with tap water removes relatively little activity from building surfaces and has only a minor effect in terms of dose reduction. However, in some cases it can be considered, especially in dry deposition scenarios, shortly after the accident and for detached houses where the dose reduction has been assessed to be moderate. The efficiency of the method can be improved significantly by using a brush in order to remove also organic materials. High pressure water treatment (through a turbo nozzle) could also be used for decontamination of roofs and walls. Other methods, e.g., sandblasting and ion-exchange, are generally expensive.

A serious problem with hosing and high pressure water treatment is controlling the water and aerosols that could contaminate the soil around the buildings and thus increase the dose rate. The water has to be collected, contaminated soil removed and the waste disposed.

Vacuum sweeping of streets

Wet sweeping or wet vacuum sweeping are suggested for the roads. If municipal road-cleaning machines (with rotating brushes and vacuum attachment) or mere mechanical rotating brooms on tractors are enough, it would be possible to sweep the streets much faster and therefore less expensively. In a series of experiments on a freshly contaminated road, the wet vacuum sweeping removed in some cases twice as much contaminants as sweeping with an ordinary broom (Andersson 1996). The efficiency of the method has been found to be greatly dependent on the amount of street dust per square meter.

Fire hosing of streets is assumed to be done with normal tap water or with a tanker lorry. In fire hosing water washes the contaminants away from the roads into the drainage system for rainwater. Dependent on the construction of the drainage system the rainwater is either led into the purification system and mixed with the purified sewage or led directly into lakes or the sea. During sewage purification about half of the contamination remains in the sewage sludge and the other half will be released with the purified sewage (Puhakainen 2004) and will eventually end up in ditches, rivers, lakes and seas.

Grass removal

As a decontamination measure, contaminated grass can be cut normally and safely deposited. Grass cutting should preferably be done with a cutter that has a collector attached. If a collector is not available, the cut grass has to be raked up. However, hand raking in large areas is not feasible. The cut grass is subsequently collected and buried at a controlled disposal site. If grass cutting is done within a few days after the dry deposition it is effective in reducing the dose. The transfer process of caesium contamination from grass to soil has been found to have a half-life of about 15 days. It is also a cheap method and because people can do it by themselves it will also relieve their anxiety.

Grass removal is most effective in a dry deposition situation and when done within two weeks after the fallout. After a few weeks it is useless. The method can also be considered in wet fallout situations.

Foliage removal

In addition to grass, trees and bushes are effective interceptors of airborne particles. By removing trees and bushes in the vicinity of buildings the dose will be reduced considerably, but only if done in the first years. It is assumed that branches of deciduous trees are cut off and conifer trees are felled. Leaves have to be collected and disposed of in the fall.

Pruning or felling of trees is effective in dry deposition situations and when done in the first month after the fallout. After the first year it is useless.

Topsoil removal

Since the downward migration of caesium is slow, scraping the topsoil will be effective for years after the fallout. Soil samples have shown that the fallout from the nuclear weapons test explosions in the sixties and from the Chernobyl accident can still be detected in the top 30 cm (Ilus 2004).

Scraping of turf, about 5 cm, is assumed to be carried out using a spade in small scale, and a digger and a front loader in large areas. The problem with scraping of soil is the generation of large amounts of waste. If fertile soil or/and vegetation is removed the method should also include reconstruction of land and planting of vegetation.

Covering contaminated surfaces with clean soil, concrete or asphalt is most applicable in small scale. Covering the contamination with clean soil and scraping the topsoil are applicable independent of the type of fallout and the time elapsed since the accident.

In *rotovating*, the contamination is mixed within the upper 10– 15 cm of soil but when using digging and ploughing methods the contamination is relocated somewhat deeper in soil. *Digging* could be considered in small scale and ploughing and rotovating in large urban areas, as in open parks or fields. During *deep-ploughing* the soil is turned up to 45 cm whereas with an ordinary plough to about 25 cm. In digging and ploughing, there is no waste generated. An especially advantageous solution would be the application of a specially constructed skim and burial plough which has approximately the same dose-reducing effect as deep-ploughing but leaves the soil quality unaffected. The efficiency of these procedures will depend greatly on the soil type. In stony soil and areas having dense vegetation the methods are not feasible.

Evaluation of clean-up actions

In order to assess the dose, costs and total amount of waste of the various clean-up actions, information is needed on the average size of the treated surfaces and on the population distribution. The size of the treated areas depends on the house type (Table IV), and the weighted average is calculated with geo-statistical data on the number of houses of a given type per square kilometer (Central Statistical Office of Finland 1996). This figure is multiplied with the estimated costs and waste per unit of the treated surface area (Table V). The avertable collective dose of a particular clean-up action is calculated by multiplying the number of persons of each square kilometer living in a given house type (Central Statistical Office of Finland 1996) with the dose estimate for the relevant house type and square kilometer.

Table VI gives the dose reduction factors estimated for this work (Andersson 1996, Moring and Markkula 1997).

The labor costs are estimated to be 25 €/hour including overheads. Digger, lorry, front loader and vacuum sweeping costs with a machinist are estimated to be 50 €/hour. The workers' dose, man-hour and the generated waste are based on the following assumptions:

Table IV. Size of the surface areas per house type that is assumed to be treated by clean-up actions.

House type	Roof m^2	Walls m^2	Streets m^2	Yard[1)] m^2
Detached houses	120	150	400	600
Row houses	300	400	700	600
Blocks of flats	450	1 000	1 000	2 000
Other type	120	150	500	600

[1)] If parks in the area are also in the treated yard, the area should be increased by 100–200 m^2.

Table V. Estimated monetary costs, waste generated and man power needed per unit of treated surface area by the selected clean-up techniques.

Clean-up action	Labour costs €/1 000 m^2	Disposal costs €/1 000 m^2	Waste kg/1 000 m^2	Working hours/1 000 m^2, per detached house
Street hosing	350	0	0	10
Street sweeping	15	1.6	100	0.3
Roof washing	750	16	10 000 water	33, 4 h/roof
Wall washing	200	16	10 000 water	11, 1.7 h/house
Grass cutting	75	0.8	10	3, 2.5 h/yard
Tree pruning	120	16	0.8	5.3, 4.3 h/ yard
Turf removal	400	800	75 000	24, 19 h/yard

Table VI. Estimated dose reduction in percents of the effective lifetime dose (70 years) for the selected clean-up techniques in a case of dry and wet deposition of ^{137}Cs.

	Type of fallout	Roof washing	Wall washing	Street sweeping	Tree pruning	Grass cutting	Turf removal
Detached houses	dry	7	8	4	9	50	60
Wooden	wet	7	7	4	1	15	75
Detached houses	dry	10	4	4	10	45	58
Brick	wet	10	3	4	1	15	72
Row houses	dry	6	2	5	6	55	71
	wet	4	1	6	1	15	76
Blocks of flats	dry	1	3	7	4	59	74
	wet	1	2	15	0	15	77

- Roofs and walls are washed using a brush and hosed with tap water. Lift frames and lorries are available.
- Grass is cut predominately by residents using small lawn mowers equipped with collectors. The grass is put into refuse sacks, the collection of which, and the waste disposal, are organized by the local officers.
- Trees and bushes are pruned or cut mainly by light machinery, collected, chipped and disposed of. The work is organized by the local officers in cooperation with the local residents.
- Streets are vacuum swept by equipment locally available. Dust and sand are collected by lorries and disposed of preferably in surface trenches together with other waste.
- Scraping of the turf (5 cm) is done by a digger and assisted by a front loader and a lorry. It is assumed that the removed soil is replaced and the yards replanted.

An avertable effective dose of 50 mSv in a week is used as the planning criteria for evacuation in Finland. Permanent resettlement of the population is recommended if the avertable lifetime dose is 1 000 mSv (IAEA 1994, ICRP 1993). On the grounds of these intervention levels, permanent resettlement in Area NPP is

Table VII. Consequence assessment for permanent resettlement of the population of Area NPP.

	Permanent resettlement
Average avertable dose (mSv)	2 260
Avertable collective dose (manSv)	63
Avertable number of cancer cases	6
Costs (M €)	400

Table VIII. Consequence assessment for evacuation and permanent resettlement of the population of Area 1.

	Evacuation days 7 – 14	Evacuation days 7 – 30	Permanent resettlement
Average avertable dose (mSv)	2	5	210
Avertable collective dose manSv)	17	46	1 800
Avertable number of cancer cases	2	5	180
Costs (M €)	5.5	16	5 100

justified and continuing the evacuation of Loviisa town for one or three weeks could be considered due to the high iodine fallout. These are, in addition to clean-up actions, the alternatives that the participants of the workshop could choose from.

Tables VII–XII give an assessment of the tangible consequences of the actions within each area. A wide range of strategies can be defined and assessed by using the information given in these tables. For example, the evacuation of the population in Area 1 could be prolonged for another week, the roofs and walls of their houses could be cleaned, the contaminated grass removed from their yards and some trees felled in front of their houses; similar clean-up actions could be implemented in Area 2, and grass cutting and street cleaning in Areas 3 and 4. An assessment of the consequences of such a strategy is easily made with the data of Tables VII–XII.

The workers' dose is estimated by considering the time in which each action should be completed. It is assumed that sweeping of streets, washing of houses and cutting of grass should and could be done in one week, pruning of the vegetation in two weeks and scraping the topsoil in three weeks. In addition to the dose caused by the clean-up action itself, i.e. the dose received outdoors, the dose caused by transportation and waste disposal is roughly estimated by using the MATERIA and MicroShield software (Markkanen 1995, MicroShield 1996). Certain work stages, such as driving a full load with machinery and especially disposing onto an open waste trench, might cause doses which exceed the dose limits for workers. For example, it is estimated that the ^{137}Cs activity in 1 m^3 of vacuum swept waste

Table IX. Consequence assessment of clean-up actions in Area 1.

	Washing roofs	Washing walls	Vacuum sweeping streets	Grass cutting	Pruning vegetat.	Scraping topsoil
Average avertable dose (mSv)	11	10	8	27	2	120
Avertable collective dose (manSv)	90	84	70	230	17	1 030
Avertable number of cancer cases	9	8	7	23	2	103
Costs (M €),	0.2	0.1	0.0	0.1	0.2	1.7
Worker dose (manSv)	0	0	0	0	0	1
Waste (1 000 kg)	3 080	4 300	96	14	1	108 000
Working days	1 300	590	36	540	960	4 300

could be 10 000 000 kBq and it alone cause the dose of 0.1–0.2 mSv in an hour and 1–2 mSv in a day to a driver of machinery in the town of Loviisa. The costs of evacuation and permanent resettlement were assessed applying methods presented in the COCO model (Haywood et al. 1991) and the RODOS system (Ehrhardt and Weis 2000; Hasemann 2000).

Table X. Consequence assessment of clean-up actions in Area 2.

	Washing roofs	Washing walls	Vacuum sweeping streets	Grass cutting	Pruning vegetat.	Scraping topsoil
Average avertable dose (mSv)	4	4	2	9	1	42
Avertable collective dose (manSv)	24	23	14	56	4	250
Avertable number of cancer cases	2	2	1	6	0	25
Costs (M €),	0.2	0.1	0	0.1	0.2	1.8
Worker dose (manSv)	0	0	0	0	0	0
Waste (1 000 kg)	3 200	4 000	103	15	1	113 000
Working days	1 300	550	39	560	990	4 500

Table XI. Consequence assessment of clean-up actions in Area 3.

	Washing roofs	Washing walls	Vacuum sweeping streets	Grass cutting	Pruning vegetat.	Scraping topsoil
Average avertable dose (mSv)	0	0	0	1	0	1
Avertable collective dose (manSv)	4	4	2	23	4	32
Avertable number of cancer cases	0	0	0	0	0	3
Costs (M €),	1.1	0.4	0.1	0.5	0.9	8
Worker dose (manSv)	0	0	0	0	0	0
Waste (1 000 kg)	13 900	17 800	450	66	5	497 000
Working days	5 700	2 450	168	2 490	4 400	19 900

Table XII. Consequence assessment of clean-up actions in Area 4.

	Vacuum sweeping streets	**Grass cutting**
Average avertable dose (mSv)	0	0
Avertable collective dose (manSv)	10	110
Avertable number of cancer cases	1	11
Costs (M €)	1.2	8.1
Worker dose (manSv)	0	0
Waste (1 000 kg)	7 000	1 070
Working days	2 600	40 000

The intervention measures could entail also non-radiological risks to the population and the workers caused by various kinds of accidents, for example, during washing roofs, cutting grass and felling trees. The risks that are directly associated with remedial actions are estimated using Finnish statistics (Central Statistical Office of Finland 2003). The Statistical Yearbook, however, does not directly give the accident statistic for clean-up actions considered here and therefore the risk is estimated using accident risks in transportation, construction and forestry. The accident rate is not significant; if all the clean-up actions are taken in Loviisa town, one statistical accident might happen. However, if houses are washed in the Helsinki metropolitan area, circa 20 accidents might happen.

Strategy selection for further evaluation

Before the workshop eight tentative strategies were defined and their tangible attributes assessed. The strategies are presented as combinations of different countermeasures to show in detail the different actions in each strategy and also to show how new strategies could be defined during the workshop (Tables XIII–XIV).

Table XIII. Tentative definition of strategies (see also colour codes in Figure 3).

Clean-up action	**Strategy**							
	max	**A**	**B**	**C**	**D**	**E**	**min**	**0**
Permanent resettlement	**L**							
Evacuation, days 7–30		**L**	**L**	**L**	**L**			
Evacuation, days 7–14						**L**		
Washing of houses	**L++**	**L++**	**L++**	**L+**	**L**	**L**		
Sweeping of streets	**H**	**H**	**H**	**L++**	**L+**	**L**	**L**	
Pruning of vegetation	**L++**	**L++**	**L++**	**L+**	**L**	**L**		
Cutting grass	**H**	**H**	**L++**	**L++**	**L+**	**L**	**L**	
Scraping of topsoil	**L++**	**L+**	**L+**	**L**	**L**			

L comprise Loviisa and eastern part of Pernaja;

L+ comprise in addition to **L**: Liljendal, Lapinjärvi and southern part of Ruotsinpyhtää;

L++ comprise in addition to **L+**: western part of Pernaja, Myrskylä, Askola, Pukkila, Pornainen and Mäntsälä;

H comprise in addition to **L++**: Artjärvi, Orimattila, Kärkölä, Hausjärvi, Riihimäki, Hyvinkää, Porvoo, Sipoo, Järvenpää, Kerava, Tuusula, Nurmijärvi, Vantaa, Espoo, Kauniainen and Helsinki.

Notes:

- Area NPP will be resettled in every strategy.
- Grass will not be cut in areas where surface soil will be scraped.
- In Strategy **max** no cleaning actions will be carried out in area **L**.

Table XIV. Health consequences and costs of the strategies.

Attributes	**Strategy**							
	max	**A**	**B**	**C**	**D**	**E**	**min**	**0**
Cancer incidents	36	83	94	114	120	210	231	261
Saved cancer incidents	225	178	167	147	141	51	30	0
Costs of clean-up actions (M €)	22	17	9	4	2	1	0	0
Costs of relocation (M €)	5 100	16	16	16	16	6	0	0
Overall costs (M €)	5 122	33	25	20	19	6	0	0

Note. The actions taken during the first week are not included in the numbers.

Tentative value tree

The value tree of Figure 5 is provided as a discussion basis.

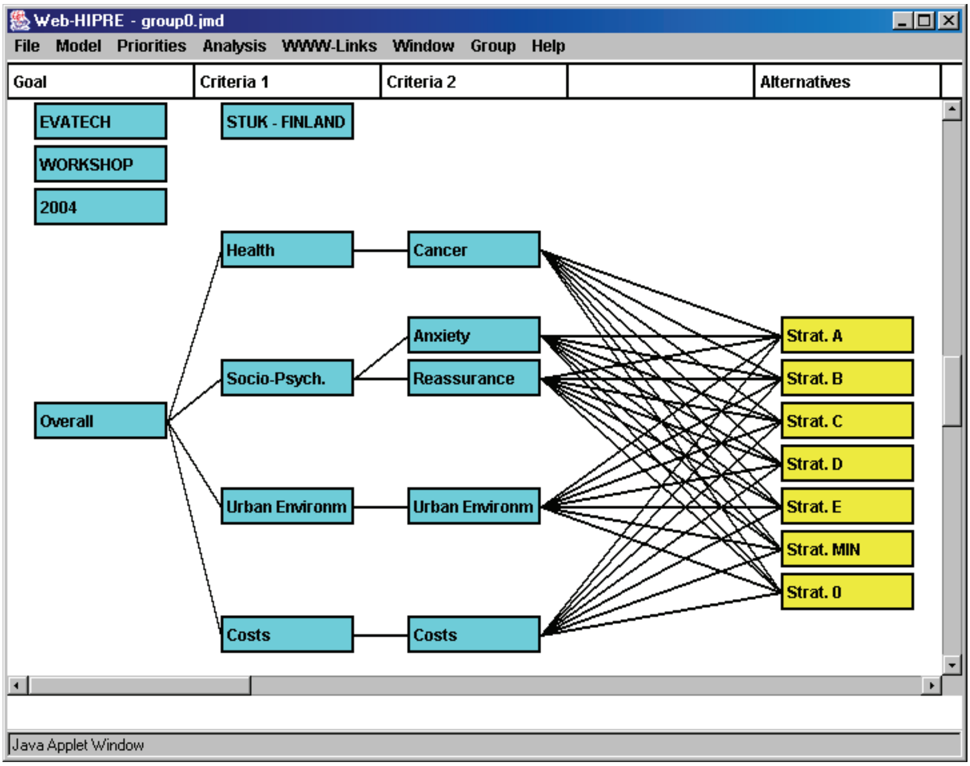

Figure 5. Tentative value tree.

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