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**R. P. Hämäläinen[1], K. Sinkko[2], M. Lindstedt[3], M. Ammann[4], A. Salo[5]**

[1] Helsinki University of Technology, System Analysis Laboratory
P.O.Box 110, FIN-02015 TKK
E-mail: raimo@hut.fi
[2] (author for correspondence) STUK – Radiation and Nuclear Safety Authority
P.O.Box 14, FIN-00881 HELSINKI
E-mail: kari.sinkko@stuk.fi
[3] Helsinki University of Technology, Systems Analysis Laboratory
P.O.Box 110, FIN-02015 TKK
E-mail: mats.lindstedt@hut.fi
[4] STUK – Radiation and Nuclear Safety Authority
P.O.Box 14, FIN-00881 HELSINKI
E-mail: michael.ammann@stuk.fi
[5] Lepolantie 54, FIN-00660 HELSINKI
E-mail: anneli.salo@pp.inet.fi

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## ABSTRACT

This work was undertaken in order to study the utilisation of decision conferencing and of the RODOS system when considering early phase protective actions in the case of a nuclear accident. Altogether four meetings with various people were organised. The meetings were attended by competent national safety authorities and technical level decision-makers, i.e., those who are responsible for preparing advice or making presentations of matters for decision-makers responsible for practical implementation of actions. In the first set of meetings the aim was to elicit the factors/attributes that have to be considered when making a decision on sheltering, evacuation and iodine tablets. No uncertainties nor a threat phase were considered but everything was assumed to happen as described in the given scenario. The theme in the second set of meetings was to study the implications of probabilities. All information was calculated with the support of the RODOS system.

In the early phases of a nuclear accident time is limited. Prestructured generic value trees or a list of possible attributes can help to save time. A possible approach is to present a large generic value tree. Either the decision-makers select the attributes that are suitable for the case in hand or the facilitator offers a choice between more structured value trees. The decision-makers then just examine the suggested value trees, check the generic tree to make sure that no important factors have been omitted and choose the appropriate one.

As in previous RODOS exercises, the participants felt that RODOS could be used for providing information but found it more problematic to use decision analysis methods when deciding on countermeasures in the early phase of a nuclear accident. Furthermore, it was noted that understanding the actual meaning of ‘soft’ attributes, such as socio-psychological impacts or political cost, was not a straightforward issue. Consequently, the definition of attributes in advance would be beneficial. The incorporation of uncertainties also proved to be difficult. The participants felt uneasy about probabilities and they focused rather on the worst possible consequences of the accident.

All in all the results from this study are promising. Further meetings, however, have to be organised in order to deepen insight into the features of the decision-making process in the early phases of an accident and to familiarise decision-makers with decision analysis techniques. And more research is needed on how to implement decision conferencing in nuclear emergency management.

# CONTENTS

# 1. INTRODUCTION

## 1.1 Background

The Chernobyl nuclear accident above all has focused attention on the need for better structured and coherent procedures for decision-making on protective actions. Decisions on countermeasures are not only driven by the need to avert dose to the population but are complex and multi-attribute problems involving, for example, monetary costs and socio-psychological factors, such as stress and anxiety. The varied response to the Chernobyl accident both in and beyond the former Soviet Union demonstrated the need for generally accepted procedures and models to ensure an integrated and coherent response to possible future accidents. Therefore the European Commission assigned the development of the RODOS, a Real-time On-line DecisiOn Support system, that would provide consistent and comprehensive support for off-site nuclear emergency management. RODOS is designed to assess, present and predict the consequences of an accident and support the decision-makers in choosing appropriate countermeasures (RODOS, 1997).

The RODOS software is designed to be a decision support system for off-site nuclear emergency management. This implies that RODOS must be able to support a wide variety of decisions-makers at several different stages of an accident. The decision support provided can be on various levels. In Table I the levels are broken down into four categories.

On the first level RODOS merely organises the incoming data and presents it to the decision-makers. Levels that provide an ever increasing support follow, ending at level 3, where RODOS interacts with the decision-makers, helping them to explore and develop their judgements and evaluations. In a sense RODOS provides decision- making support only at level 3, whereas on the other levels it mostly organises and presents information (Ahlbrecht *et al*, 1997).

As part of the RODOS project a series of decision conferences were arranged in Finland, where the RODOS system was tested in simulated nuclear emergencies. Previous conferences within the radiation protection community (see for example French *et al*, 1993 and French *et al*, 1996) have mainly used a two-day decision conferencing approach. Other forms of decision conferences have also been suggested. For example, the spontaneous decision conferencing concept where the whole process can be accomplished in just a few hours and with minimal preparations beforehand (Hämäläinen and Leikola, 1995). In the early phases of a nuclear

***Table I.*** *Decision support can be provided at various levels (Ahlbrecht et al, 1997).*

| Level of decision support | |
|---|---|
| Level 0 | Acquisition and checking of radiological data and their presentation, directly or with minimal analysis, to decision-makers, along with geographical and demographic information available in a geographical information system. |
| Level 1 | Analysis and prediction of the current and future radiological situation (i.e., the distribution over space and time in the absence of protective actions) based upon monitoring and meteorological data and models. |
| Level 2 | Simulation of potential protective actions (e.g., sheltering, evacuation, issue of iodine tablets, food bans, and relocation), in particular determination of their feasibility and quantification of their benefits and disadvantages. |
| Level 3 | Evaluation and ranking of alternative protective action strategies in the face of uncertainty by balancing their respective benefits and disadvantages (e.g. costs, averted dose, stress reduction, social and political acceptability) taking account of societal value judgements as perceived by decision makers. |

accident it is not possible to use two days for conferencing, rather the decisions have to be taken within few hours or some decisions even within minutes. Therefore, this shorter type of approach was used in the conferences in this study. It is moreover useful in planning, training and exercises.

Another approach would have been the interview technique in order to analyse the decision situation from the perspective of different stakeholders. Decision analysis interviews have been used to increase stakeholders' participation in environmental decision-making (Marttunen and Hämäläinen, 1995). This is an approach that could also be useful in nuclear emergency management. See, for example, Keeney (1980) or Bäverstam *et al* (1997) for more discussion on how decision analysis can be used in the radiation protection context.

Decision analysis also brings other benefits. The structuring of the decision problem helps in communication with the public and also in justifying the decision afterwards. In political or environmental decision-making this can be the critical factor (Hämäläinen, 1988, 1992, Hämäläinen and Karjalainen, 1992, Hämäläinen and Leikola, 1995, Miettinen and Hämäläinen, 1997). In nuclear emergency management the decisions will be closely scrutinised by the media and the public and there is a demand for well-structured and trans- parent decision-making.

An advantage of this study in comparison with many research studies is that the real decision-makers and experts took part in the decision conferences. Thus the level of knowledge and commitment to the issues was guaranteed and the conclusions drawn have a higher degree of reliability.

## 1.2 Objectives of the Study

The main objectives of this study were as follows:

- To study and develop the applicability of decision support systems for different situations. In the early hours of an accident there is hardly time to model the decision to be taken; rather the decision has to be based on intervention levels studied and considered beforehand and on guidance given by a decision support system (DSS). In the later phase of an accident, however, there is time and need to perform sophisticated analyses.

- In the early hours of an accident uncertainties are dominant concealing factors which might become apparent in the later hours of the accident. Probabilities are also difficult to articulate. Furthermore, the interpretation of values, trade-offs and even wording can be quite different depending on whether they are determined by experts or by decision-makers. Attributes and probabilities have to be studied at different meetings.

- The values/attributes that have to be considered when setting actual intervention levels for a prevailing situation have to be identified: international recommendations are based on generic or holistically performed analyses. Only a few analyses exist where all important attributes and their relative importance for the decision have been considered and discussed explicitly. Generic intervention levels are given commonly as a ‘range within which the optimised intervention levels are expected to be found’ (ICRP 63). This stems from the fact that accidents, environments and circumstances can be very different.

- The emergency situation has to be managed as a whole, i.e., single protective actions have to be bundled into overall strategies in the affected area: although protective actions could be optimised independently from each other, in practice the actions are dependent or sequential, e.g., agricultural countermeasures are dependent on sheltering and/or evacuation. Differences between urban and rural areas should be addressed.

- To study the RODOS software package in decision conference settings: how could the RODOS software be used in a decision conference setting? What information can RODOS provide? Does it offer useful what-if analyses? What information experts are looking for and what information is desired by decision-makers with a higher level of responsibility?

- The basic objective was to provide a shared understanding between the decision-makers and the radiation safety experts on concerns and issues related to decisions on protective actions after a nuclear accident.

## 1.3 Research Methods and Organisation

A series of decision conferences were held in Finland to study the use of decision analysis methods and the RODOS software in practice. The decision conferences were arranged in co-operation between STUK and the Systems Analysis Laboratory (SAL). STUK was responsible for the development of the accident scenarios and for contacts with the participants in the conferences. STUK operated the RODOS software. SAL was responsible for the modelling, decision analysis approaches and for the implementation of the decision support software as well as for the facilitation of the conferences.

The first Finnish conferences focused on early phase countermeasures i.e., iodine tablets, sheltering and evacuation. The primary approach studied was to use a decision conferencing format to model the early countermeasure decisions, elicit preferences and decide on the appropriate countermeasure strategy. How this modelling should be done and what factors are important were subject analysed at the conferences. Whether to use prestructured value trees or other types of shortcuts was another issue that was studied at the conferences.

Figure 1 is a flowchart showing the principle steps in conducting decision conferences. As can be seen from the figure, a conference is an iterative process, where at each new stage the results are examined and revised if necessary. From time to time it might also be necessary to go back to an earlier stage.

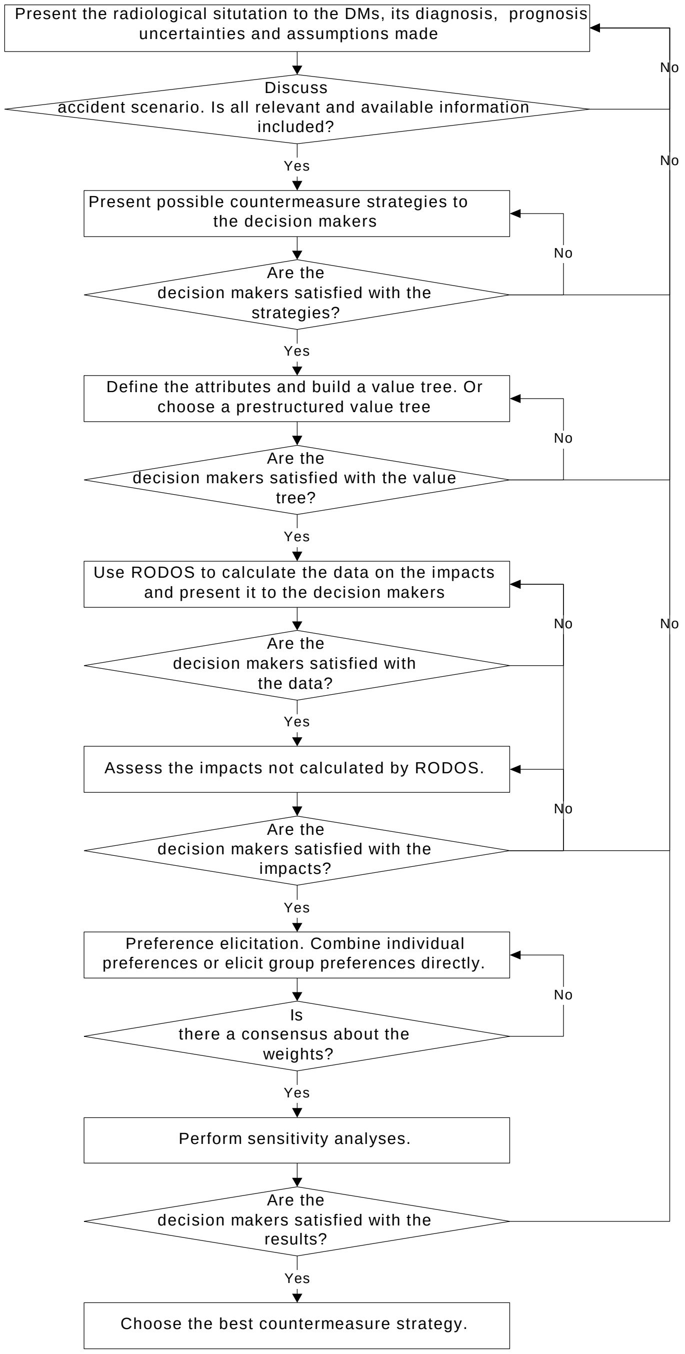



***Figure 1.*** *Flowchart of running a decision conference supported by RODOS.*

As described in this report, not all these steps were actually conducted on line during the conferences: the simulation of the radiological situation and the generation of countermeasure strategies, together with the assessment of their consequences, was done in advance. The participants were supplied with an information package, comprising thematic maps of the radiological situation showing dose values, an animation of the dispersion and assessments of health and economic consequences. RODOS was used to prepare this information package.

# 2. FINNISH DECISION CONFERENCES ON EARLY PHASE COUNTERMEASURES

## 2.1 Meetings

As part of the RODOS system development program STUK arranged a series of decision conferences in 1997 and is to arrange another one in 1998. The first series of conferences, i.e., those described in this report, focused on the early phases of an accident. In the second series of decision conferences decision-making on later phase protective actions will be dealt with. All in all, four meetings were held (one meeting was divided into two sessions) as outlined in Figure 2. In addition, one less formal overture meeting was organised early in the spring for STUK personnel only. The countermeasures considered were the issuing of iodine tablets, sheltering, and evacuation. In the first phase of the decision conferences the emphasis was on identification of the attributes and values and in the second phase how to incorporate uncertainty handling in the analysis.

The conferences usually started with a short briefing on the accident and on the goals for the conference. Then the facilitator performed the decision modelling part of the conference. He used slides and was assisted by two analysts, one for the decision-aiding software and one for the RODOS software. The computer screens were projected onto the wall, which enabled the decision-makers to follow the decision model simultaneously when it was being constructed and new insights generated.

## 2.2 First Phase of the Decision Conferences: Attributes and Values

### 2.2.1 Background

The first phase of the decision conferences ended with a meeting on October 7th at STUK. Preceding that meeting two problem structuring sessions were held one week apart. At the structuring sessions the problem was structured and a value tree built. The results from these sessions were then given to the participants in the last meeting, with the mutual understanding that the results had been generated by another group of experts. Except for two people, the participants in the structuring session and those in the last meeting were not the same. It is contrary to normal procedures in decision conferencing that the value tree is built by one group and then used by a different group of decision-makers. However,

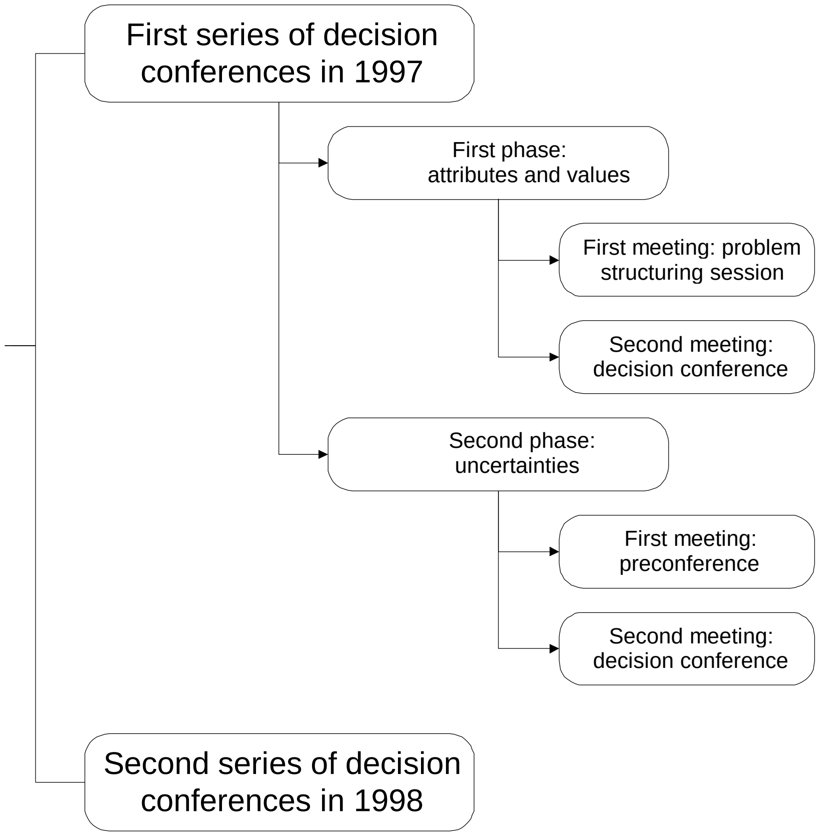



***Figure 2.*** *Flowchart of the conferences arranged by STUK.*

because of the time limits associated with the early phases of a nuclear accident, this type of approach was studied. The question was whether a prestructured value tree could be given to the decision-makers at the beginning of the conference with the provision to restructure it if considered necessary.

The case used in this exercise was constructed in a way that no uncertainties were included. In the early phases of an accident the uncertainties are such dominant factors that everything else is obscured. Therefore, it was decided first to study attributes, values and trade-offs separately without any interference of uncertainties and include uncertainties only in the second phase of the decision conferences. Thus this exercise can be seen as an afterthought, i.e., what countermeasures should have been taken knowing everything that happened during the accident.

The objectives of the first phase of the decision conferences were:

- To define the factors and attributes of importance when deciding on countermeasures, i.e., on issuing iodine tablets, sheltering and evacuation.

- To define the intervention levels, i.e., the timing and duration, and the area for each action. This objective was included for planning purposes and to see if decision conferencing could provide insight into the definition of intervention levels.

- To develop a strategy by combining single protective actions and defining their implementation time and, at the same time, taking into account the differences between rural and urban areas.

The following decision-making issues were to be considered:

- To build a value tree.

- To study the anchoring on the international recommendations for intervention levels.

- To discuss whether it is feasible to treat different population groups differently, e.g., to give iodine tablets only to children.

- To discuss whether to use dose, the number of cancer cases or the decrease in expected lifetime as an attribute.

For the purpose of the analysis it was assumed that a hypothetical core-damaging and containment leak accident had occurred at the Loviisa nuclear power plant in Finland, leading to contamination of the environment. The probability of the occurrence of such a containment failure accident leading to a release in real life is estimated to be less than one in 100,000 per reactor-year.

The release scenario for the Loviisa nuclear power plant had been chosen based on containment failure classification. There are several possible containment event tree branches in each containment failure group and the release fractions are often given as the group's cumulative probability distribution. However, in this case, point estimate values were given as in Table II, i.e., values of a chosen event tree branch without a distribution. These values were based on the assessment of the plant and STUK's nuclear safety experts.

The main events causing this accident had been a small LOCA (loss of coolant) at 9 o'clock in the morning, radionuclide release into the containment and a break of the reactor cavity at 1 o'clock the next night. The release therefore occurred 16 hours after the shutdown, and lasted for 24 hours in two phases. During the first three hours nearly all noble gases were released. The release of other nuclides started almost immediately after the containment failure and continued more or less constantly over the next 24 hours. The release height was ground level (Niemelä, 1997).

The time chosen for the accident was the middle of August. Weather data were based on real weather conditions from 1996. In southern Finland the weather was stable with steady winds from the south-east at night and the next morning (the plume was hence moving north-west). The wind speed was 5 m/s and atmospheric stability was neutral. The wind then turned during the day, first to the east, then north-east, east, south, then west when the wind speed went down to 1 m/s and, finally, to the north during the next night. There was no rain in the area.

Figure 3 shows a thematic map illustrating the radiological situation. The effective dose under normal living conditions is displayed on a map of the mainly affected area.

### 2.2.2 Problem Structuring Session

The problem structuring sessions were held with five experts from STUK and one retired employee. The structuring session was divided into two parts; the first part, which lasted for three hours, was held on 25th September and the second part, which lasted for two hours, was held a week later. Between the sessions the value tree was constructed and the attributes specified. Two of the participants were unable to attend the second session.

***Table II.*** *Release point estimates assumed for the hypothetical accident, venting into containment in Loviisa NPP for the first phase of the decision conferences.*

| **Nuclide group** | **Release fraction** |
|---|---|
| Noble gases | $1.0 \cdot 10^{-0}$ |
| Iodine total | $9.6 \cdot 10^{-2}$ |
| Alkaline-group (Cs, Rb) | $8.9 \cdot 10^{-2}$ |
| Tellurium-group (Te, Se, Sb) | $1.5 \cdot 10^{-1}$ |
| Alkaline earth-group (Sr, Ba) | $1.3 \cdot 10^{-2}$ |
| Ruthenium-group (Ru, Mo, Tc) | $2.6 \cdot 10^{-4}$ |
| Lanthanide-group (LA, Nb, Zr, Cm, Ce, Nd, Pm, Sm, Eu, Pu, refr. Ox. Nb, Zr) | $1.4 \cdot 10^{-2}$ |

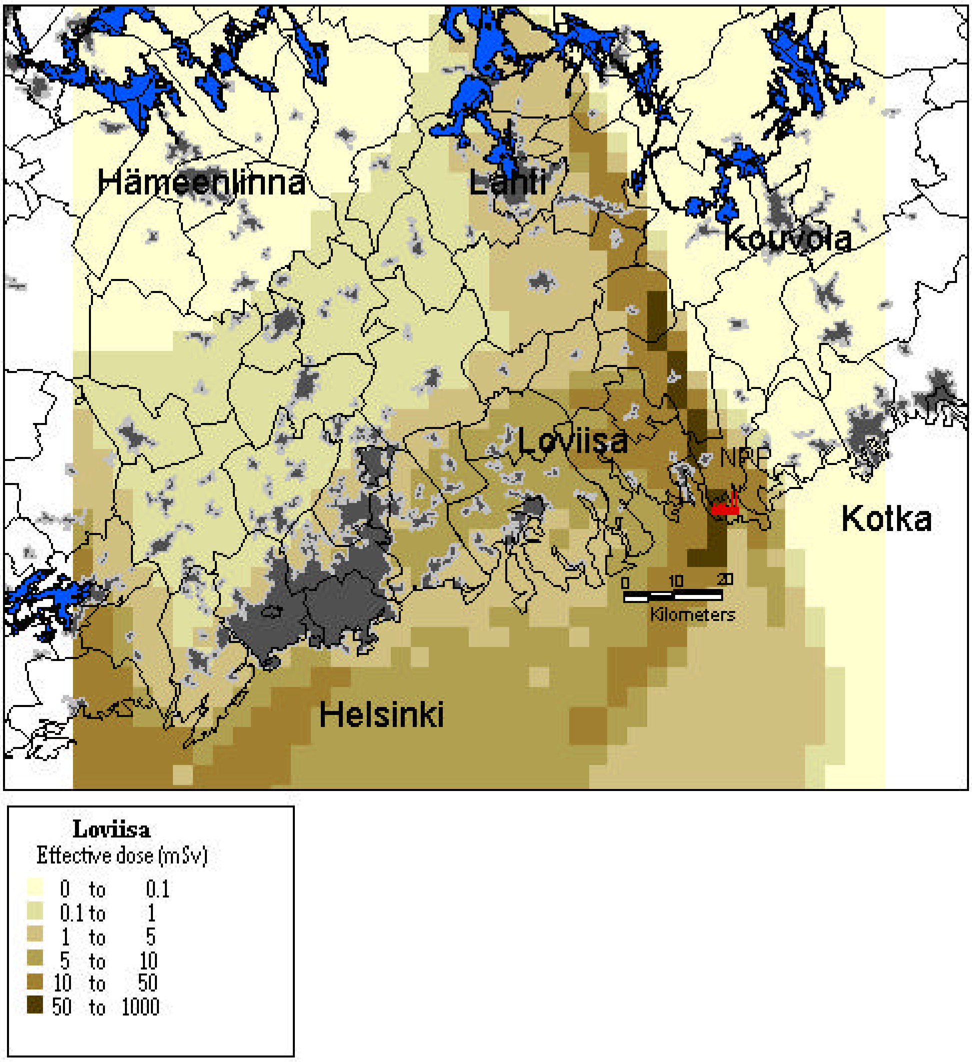



***Figure 3.*** *Spatial effective dose distribution in the Loviisa release scenario. The affected area includes the cities of Lahti to the North and Helsinki to the West of Loviisa.*

The first part of the problem structuring session was mostly a brainstorming event. With the help of the facilitator the participants tried to imagine all the factors that might be important when deciding which countermeasures to employ. The idea was to imagine the most drastic countermeasure possible, which in this case would have been the evacuation of Helsinki, and to reflect on the attributes that have to be considered in a decision concerning this evacuation. This method was hoped to make it easier for the participants to think of all relevant factors. No thoughts about the relative importance of the attributes were made. Between the sessions the resulting attributes were structured into a preliminary value tree (see Figure 4).

The brainstorming approach proved successful. The participants come up with many factors that might be crucial; and they did not have to commit themselves. If the process started with a direct structuring of the value tree, the participants might feel that they are defining the importance of the attribute at the same time and this might inhibit them.

Thus the brainstorming approach was a good way to start the process and to get the participants involved in decision modelling.

The preliminary value tree is not suitable for a decision analysis technique as such; it is too complex. It is also difficult to distinguish the costs between the state, industry, and citizens. Eventually costs are anyway passed on to the citizens/taxpayers. The tree can, however, serve other useful purposes. It can, for instance, be used to show the public which factors were considered in the process, even if some of them were to be dropped out later because of their insignificance for the decision in hand.

Based on the preliminary tree a more structured value tree was built between the sessions. In the second session both trees were examined, the structured one chosen and modified where necessary. The resulting value tree is in Figure 5. The attributes and their respective units are explained in Table III. The choice of whether to use the *number of cancer deaths* or the *number of cancer incidents* as a unit is not a straightforward one. For example, one participant later remarked that the expected fatality rate for thyroid cancer is 10% in children. Therefore, there is a substantial difference between using the *number of incidents* or the *number of deaths* as a unit.

During the second problem structuring session four countermeasure strategies were briefly presented and discussed (Table IV).

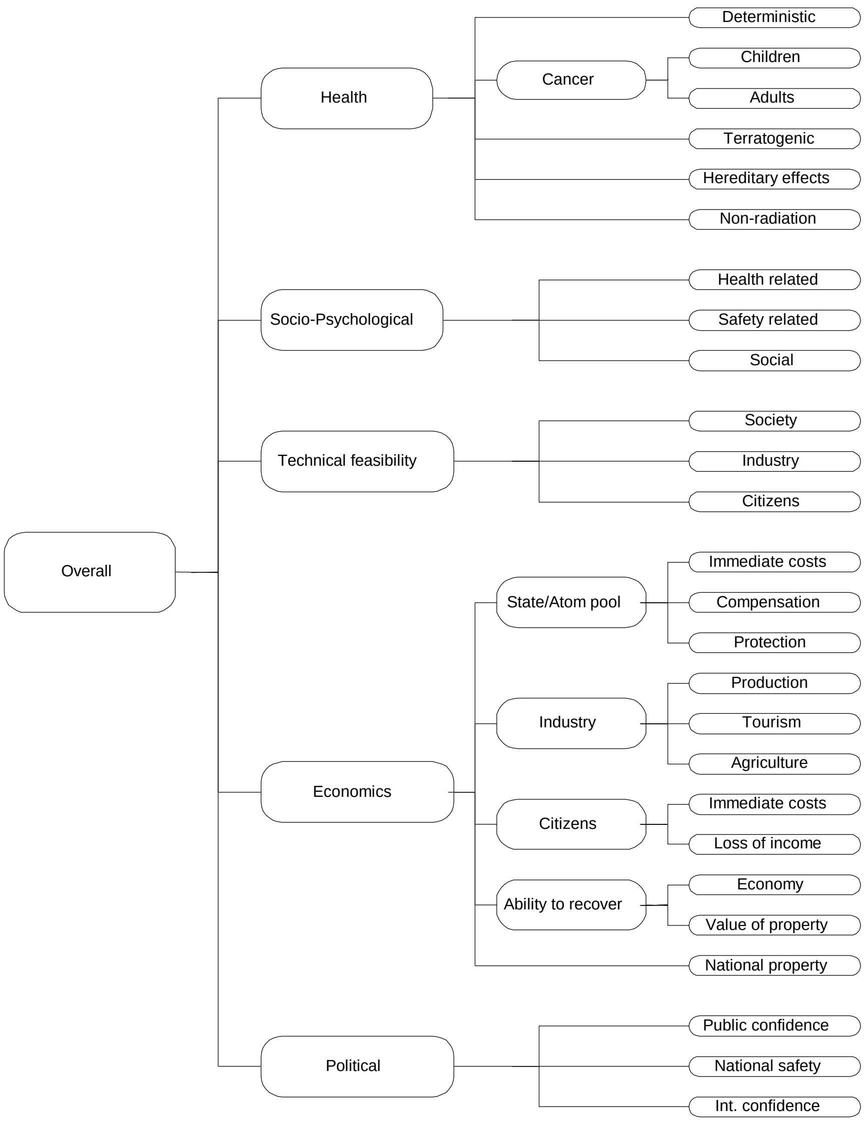



***Figure 4.*** *Preliminary value tree in the first phase of the decision conferences.*

### 2.2.3 Finnish Decision Conference - Case: Loviisa

The last meeting was held on October 7th at STUK and then the decision conferencing format was followed more closely. In addition to the four organisers seven participants attended the conference: three people from STUK (one of them had already participated in the problem structuring session), two people from the Finnish power companies (IVO and TVO), a psychologist (Helsinki University) and one retired employee of STUK (already participated in the problem structuring session).

As mentioned earlier, this meeting was held under the assumption that an expert group had earlier met and analysed the accident situation. This stepwise process roughly represents the procedure used in STUK when preparing countermeasure recommendations. The results of that meeting (i.e., the value hierarchy constructed) were therefore made available to the participants. Their task was to come up with a suggestion for a countermeasure strategy,

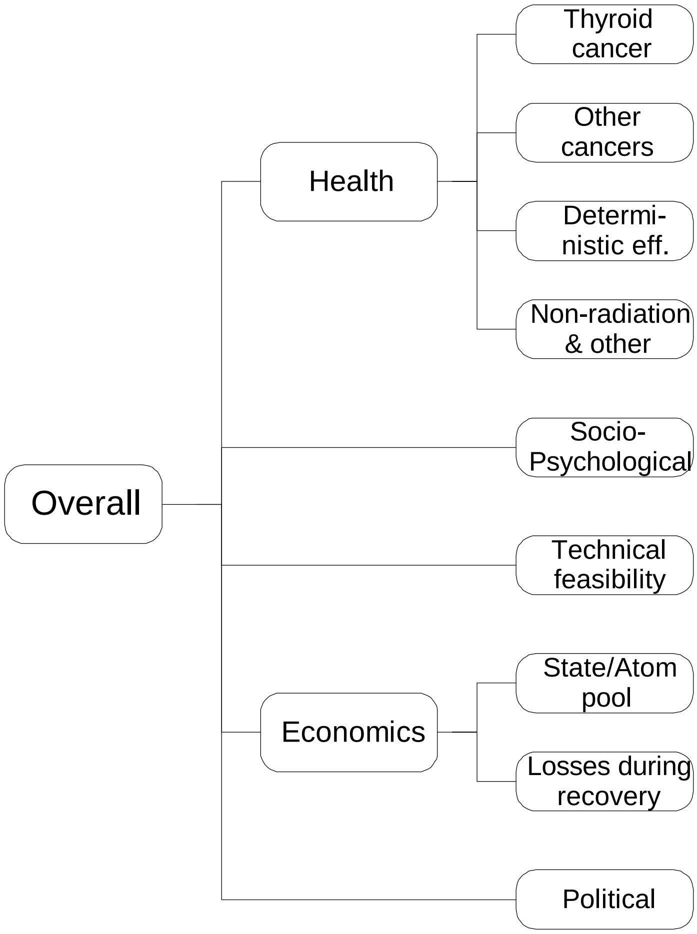



***Figure 5.*** *Value tree after the problem structuring session in the first phase of the decision conferences.*

***Table III.*** *Description of attributes in the first phase of the decision conferences.*

| Attribute | Description | Unit |
|---|---|---|
| **Health** | | |
| Thyroid cancer | thyroid cancer in children | number of cancer deaths/incidents |
| Other cancers | other types of cancer | number of cancer deaths |
| Deterministic effects | deterministic radiation effects in workers | number of deaths/incidents |
| Non-radiation and other | traffic accidents, changes in medical care (moving hospital patients), | number of deaths/incidents |
| **Socio-Psychological** | | |
| | health or safety related (anxiety about one's own health and family, reassurance), disturbances in social relations and lifestyle | very negative - very positive |
| a) Health and safety | health or safety related (anxiety about one's own health and family, reassurance) | very negative - very positive |
| a) Social | disturbances in social relations and lifestyle | very negative - very positive |
| Technical feasibility | overall feasibility, infrastructure, distribution of food etc., manpower | very low - very high |
| **Economics** | | |
| State/Atom pool | direct costs, compensation costs | ECU |
| Losses during recovery | in production (agriculture, tourism etc.) | ECU |
| **Political** | public confidence, transparency of policies, national security, international confidence, image | very negative - no change |

a) The *socio-psychological* attribute was divided into two attributes, *health and safety* and *social* at the last meeting of the first phase.

which later the same evening was to be presented to the authorities responsible for the implementation of actions. Thus, an attempt was made to simulate an emergency situation where a decision has to be made within a few hours.

The participants in this meeting examined the suggested value tree and made slight modifications. They felt that the *socio-psychological* attribute could not be assessed as such, but needed to be subdivided into two attributes; *health and safety* and *social*. The unit of measurement for the attribute *thyroid cancer* was also changed from the *number of cancer deaths* to the *number of cancer incidents*, because it was felt to describe the impact better. Thyroid cancers affect children and therefore the cancer incidents, too, are significant. Moreover, even a slight increase in thyroid cancer cases caused by an accident could be seen in statistics and the occurrence would be followed afterwards. The resulting value tree is to be found in Figure 6 and the descriptions of the attributes are set out in Table III.

The four alternatives, or countermeasure strategies suggested in this exercise have been defined by three different sets of dose criteria. A reluctant, moderate and rigorous intervention policy was adopted, corresponding to high, medium and low dose criteria, respectively. The time schedule for the actions has been the same in all strategies: if the corresponding dose criterion is exceeded, evacuation is implemented and iodine tablets are taken before the plume arrives, and people are sheltered during its passage time. In Table IV the dose criteria and the consequences of the actions are given in terms of area, the number of people affected, cancer deaths and costs. No intervention at all is the baseline strategy and its consequences are also given in the table. The consequences have been assessed by means of the RODOS modules PROGNOSE (prognosis of the radiological situation) and EMERSIM (emergency simulation).

After a few discussions the participants agreed on a rough approximation of the impacts of the four strategies on the different attributes. The attributes, the units of measurement, and the impacts of the four strategies are given in Table V. The impacts on the attributes thyroid cancer, other cancer and economics have been calculated by means of or with support from EMERSIM. Impacts on all other attributes were assessed by the participants during the meeting.

To study how comfortable the participants feel with different weighting techniques, three participants were asked to give their preliminary preference statements, so that the weights of the different attributes could be calculated. The first participant used the SMARTER technique and the other two the SMART technique[1]. The preferences were elicited in a sequential order and in an open way, that is, the statements were given orally in front of the other participants. The preferences were given quite rapidly and with very little discussion. The idea was not to find precise and accurate weights, rather to study, on the one hand, the applicability of this type of approach, and on the other hand, to give the participants a demonstration of the methods available. The resulting weights are found in Table VI and the overall rankings are shown in Figures 7-9.

[1] In the SMART technique the weights are calculated by ranking the importance of the changes in the attributes from the worst attribute level to the best level and then by giving the least important attri bute a score of 10 and the rest of the attributes a scoring relative to that. In the SMARTER technique a decision-maker is only asked to rank the attributes. The weights are calculated from this ranking.

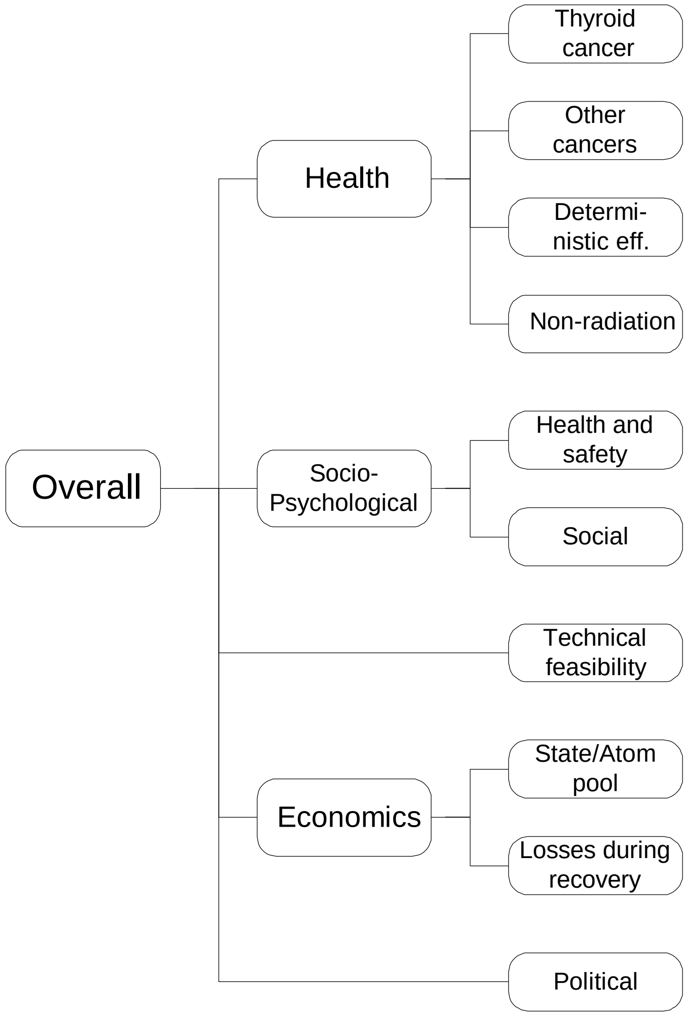



***Figure 6.*** *Final value tree in the first phase of the decision conferences.*

***Table IV.*** *The four countermeasure strategies considered in the first phase of the decision conferences and their consequences.*

| | No action | Reluctant Strategy | Medium Strategy | Rigorous Strategy |
|---|---|---|---|---|
| *Dose criteria [mSv]* | | | | |
| Evacuation | - | 500 | 50 | 5 |
| Sheltering | - | 50 | 5 | 0.5 |
| Stable Iodine | - | 1000 | 100 | 10 |
| *Consequences* | | | | |
| Evacuation Area [km2] | 0 | 0 | 224 | 4500 |
| Sheltering Area [km2] | 0 | 224 | 4500 | 11200 |
| Iodine Area [km2] | 0 | 64 | 1540 | 7760 |
| Population in Evacuation Area | 0 | 0 | 5700 | 845000 |
| Population in Sheltering Area | 0 | 5700 | 845000 | 284000 |
| Population in Iodine Area | 0 | 1950 | 355000 | 142000 |
| Cancer deaths [No] | 563 | 551 | 431 | 21 |
| Evacuation costs [MECU] | 0 | 0 | 22.4 | 3320 |
| Sheltering costs [MECU] | 0 | 0.2 | 32.7 | 9.5 |
| Costs due to cancer [MECU] | 41.2 | 40.1 | 32.4 | 1.5 |
| Sum [MECU] | 41.2 | 40.1 | 87.5 | 3330 |

***Table V.*** *The impacts of the strategies considered in the first phase of the decision conferences.*

| Attribute | Unit | No action | Reluctant Strategy | Medium Strategy | Rigorous Strategy |
|---|---|---|---|---|---|
| *Health* | | | | | |
| Thyroid cancer | No of incidents | 1000 | 900 | 700 | 1 |
| Other cancers | No of deaths | 400 | 300 | 220 | 20 |
| Deterministic | No of deaths | 0 | 1 | 1 | 2 |
| Non-radiation | No of deaths | 0 | 3 | 7 | 10 |
| *Socio-Psychological* | | | | | |
| Health and safety | neg - pos (100 - 0) | 80 | 80 | 70 | 40 |
| Social | neg - pos (100 - 0) | 0 | 5 | 40 | 80 |
| *Technical feasibility* | low - high (100 - 0) | 0 | 1 | 10 | 100 |
| *Economics* | | | | | |
| State/ Atom pool | MECU | 40 | 40 | 80 | 3 300 |
| Losses during recovery | MECU | 170 | 170 | 170 | 1 670 |
| *Political* | neg- no change (100 - 0) | 100 | 30 | 30 | 80 |

Although the preferences were given with little deliberation, some observations about the rankings can be made. The choice of the Rigorous strategy by DM 1 and DM 3 would mean that most of Helsinki has to be evacuated. The cost is also quite high, about 10 million ECU per averted cancer death. This amount of investment is clearly outside the range recommended by international organisations, i.e., 0.05 - 1.8 million ECU (3000 - 100,000 US$ per manSv, see e.g. ICRP 63, IAEA Safety Series 109). Another viewpoint has been presented by Keeney

(1994). Environmental regulations may include lower wages, higher taxes and, at the end, less income available for health care, nutrients etc. According to the estimation of Keeney, roughly 10 million ECU paid for regulation will cause one statistical fatality. No real discussion on the results was held, so it cannot be stated whether the participants would truly be willing to suggest the rigorous strategy. But it is interesting to note that at least the first estimates produced very tough action plans.

The rankings were also examined with sensitivity analyses. Figure 10 presents the sensitivity analyses on the weight of the higher level *health* attribute. From the graphs it can be seen that the results from DM 1 and DM 2 are quite sensitive to small variations in the weight. A small increase or decrease in the weight would change the ranking. The ranking of DM 3, on the other hand, is robust. A very large decrease in the weight put on the health factor is needed to change the ranking. These types of analyses are very important in helping the decision-makers understand and interpret the results correctly. The results of this sensitivity analysis DM 1 and DM 2 indicate that it would be useful to examine the rigorous and medium strategies more closely and perhaps develop a new intermediate alternative.

***Table VI.*** *The weights given in the first phase of the decision conferences.*

| **Attribute** | **Least Preferred Level** | **Most Preferred Level** | **DM 1 SMARTER** | **DM 2 SMART** | **DM 3 SMART** |
|---|---|---|---|---|---|
| Thyroid cancer | 1000 | 0 | 0.337 | 0.250 | 0.235 |
| Other cancers | 400 | 0 | 0.212 | 0.250 | 0.188 |
| Rescue workers | 2 | 0 | 0.013 | 0 | 0.047 |
| Non-radiation | 10 | 0 | 0.013 | 0 | 0.012 |
| Health and safety | 100 | 0 | 0.076 | 0 | 0.235 |
| Social | 100 | 0 | 0.030 | 0 | 0.118 |
| Technical feasibility | 100 | 0 | 0.107 | 0 | 0.047 |
| State/ Atom pool | 20000 | 0 | 0.149 | 0.250 | 0 |
| Losses during recovery | 10000 | 0 | 0.013 | 0.250 | 0 |
| Political | 100 | 0 | 0.051 | 0 | 0.118 |

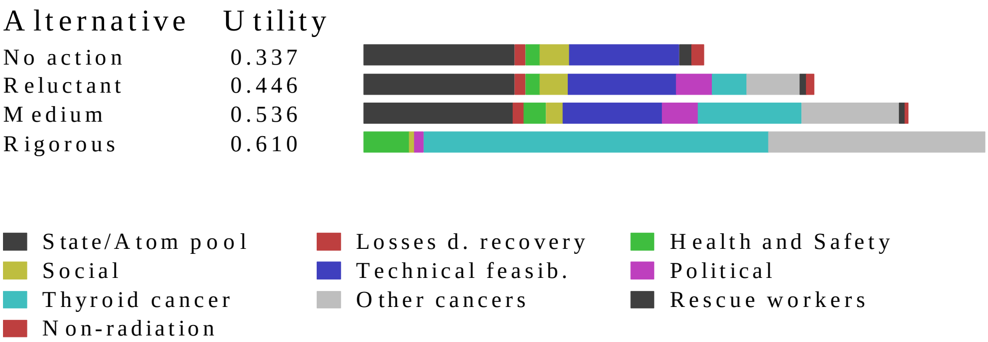



***Figure 7.*** *Ranking of strategies by* DM *1 - first phase of the decision conferences.*

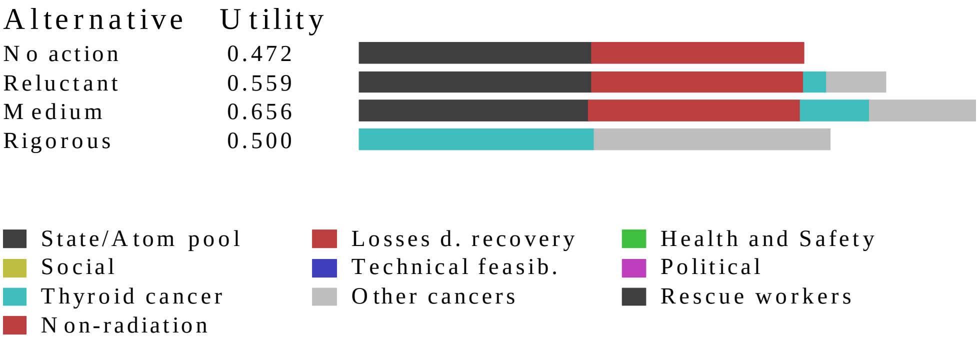



***Figure 8****. Ranking of strategies by* DM *2 - first phase of the decision conferences.*

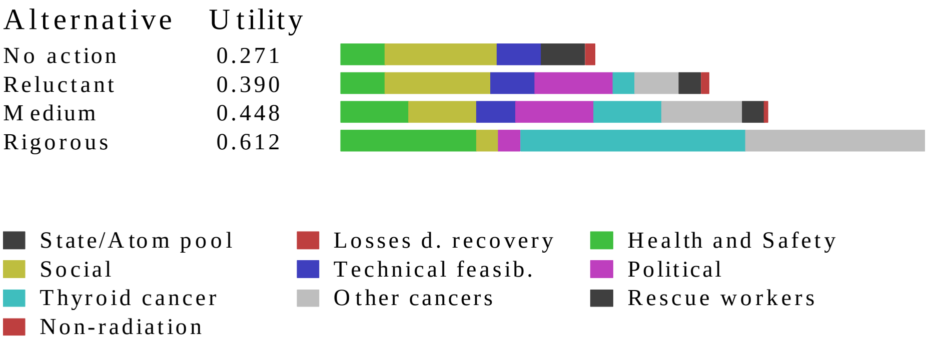



***Figure 9.*** *Ranking of strategies by* DM *3 - first phase of the decision conferences.*

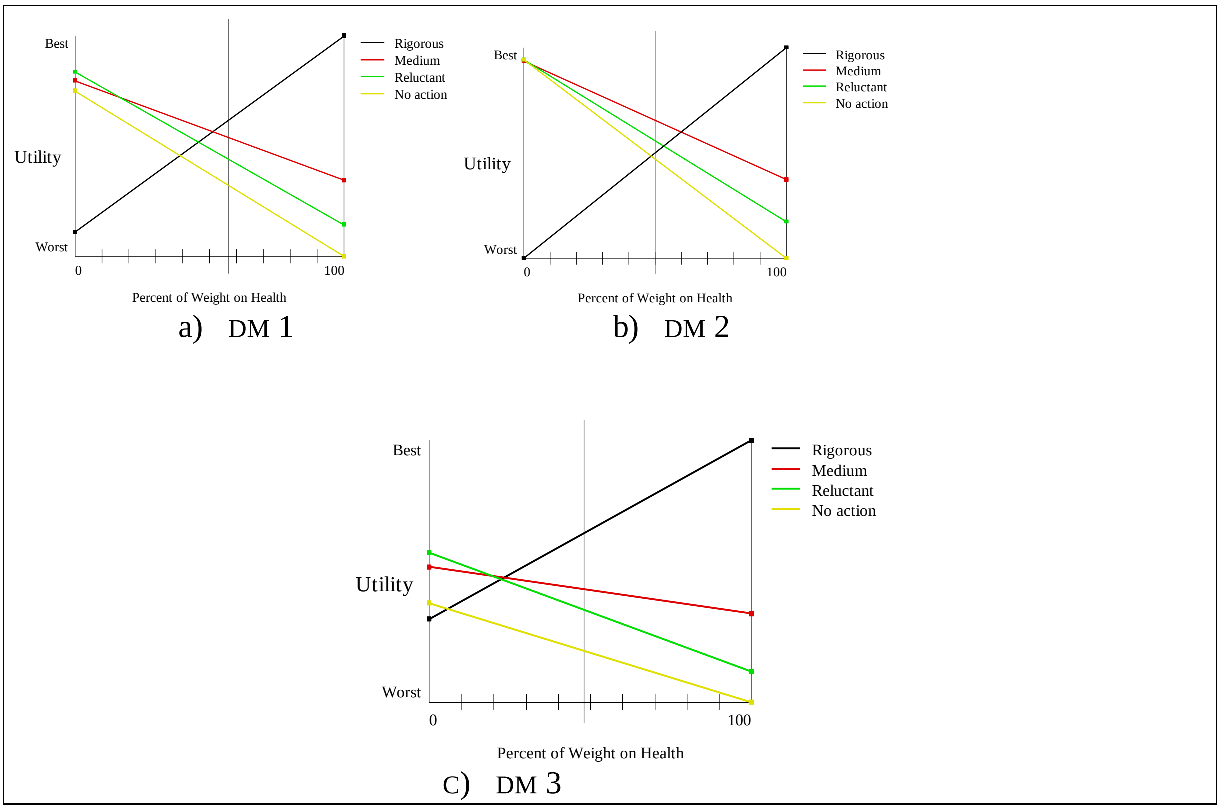



***Figure 10.*** *Examples of sensitivity analyses performed during the first phase of the decision conferences.*

### 2.2.4 Questionnaire

To achieve a better understanding of participants' opinions and thoughts about the decision conference, a questionnaire was sent to all participants after the first phase of the decision conferences. Eight participants out of the total of eleven in the first phase took part in the survey. In addition, the same questionnaire was sent to two persons working on the RODOS project at STUK to enable an analysis to be made of the differences in opinion between those involved in the RODOS project and the potential users of results.

Table VII presents the answers to the questions about the exercise in general. It can be seen from the answers that the participants mostly have a neutral view regarding the usefulness of the RODOS software and the usefulness and successfulness of the decision conference. In general, the people working on the RODOS project took a more positive attitude towards RODOS. Concerning the suitability of the software, the general opinion seems to be that it can be used for training and planning purposes and as an extra tool in real-life cases, but not as the primary decision aid in the early phase of an accident. The people working on the project again took a more optimistic view.

There was mutual agreement that it is important that the software be able to provide details on the data relevant to the decision, i.e., estimated doses, effectiveness of the countermeasures, health effects and costs. But when it comes to helping in the actual decision-making, for example by providing pre-programmed value trees, sets of preferences or pre-programmed accident scenarios, opinions were divided. Some were against it, some in favour, and some took a neutral view on the matter.

Table VIII sets out the answers to the questions about the decision analysis technique used in the first phase of the decision conferences. The persons working on the RODOS project took a very positive view of the suitability and helpfulness of using a decision analysis technique in this type of context. The participants were, however, more reserved, and some even questioned the whole concept. All agreed on the importance of being able to justify and explain the decision afterwards, but at the same time the participants were not convinced that using this type of approach helps it. The questionnaire confirms an attitude already noticed during the discussions, namely that the participants did not believe that is possible to describe a strategy's impact on non-quantifiable factors in a single phrase or number. Yet most decision analysis techniques require such preference statements.

The opinions of the participants seem to be quite similar to the observations made in the earlier exercises (Ahlbrecht *et al*, 1997).

### 2.2.5 Summary and Conclusions of the First Phase

The first phase of the decision conferences focused on early phase countermeasures after a nuclear accident. No uncertainties were included, so the conferences can be seen to have dealt with what countermeasures should have been taken, knowing everything that happened. A problem structuring session was held where a value tree was built. In the decision conference this tree was slightly modified and then applied. Four countermeasure strategies were investigated, their impacts examined and some preliminary preferences elicited. Finally the resulting rankings were examined using sensitivity analyses.

***Table VII**. Answers to the questions about the first phase of the decision conferences.*

| **Decision Conference** | ☹☹ | ☹ | 😐 | ☺ | ☺☺ |
|---|---|---|---|---|---|
| Are these types of exercises important? | | 1 | 2 | 4 | 3 |
| How well did the exercise meet your expectations of it? | | 2 | 2 | 6 | |
| Did the exercise provide you with new ideas and information? | 1 | 3 | 1 | 4 | 1 |
| Do you feel that your opinions were understood and included in the process? | | | 2 | 6 | 1 |
| All in all, how would you rate the exercise? | | 1 | 4 | 3 | 1 |
| How suitable do you believe the RODOS software (when finished) will be for early phase countermeasures? | | | | | |
| • for training purposes? | | 1 | | 4 | 5 |
| • to be used in real-life accidents as the primary decision aid? | | 4 | 3 | 2 | 1 |
| • as an extra tool to be used in real-life accidents (e.g. by providing benchmark cases)? | | | 2 | 7 | 1 |
| How important is it that RODOS be able to provide the following data: | | | | | |
| • estimated doses | | | 1 | 1 | 7 |
| • estimated effectiveness of countermeasures (reduced dose) | | | | 3 | 7 |
| • estimated health effects | 1 | | 1 | 1 | 7 |
| • cost of countermeasures | | | | 4 | 5 |
| • pre-programmed value trees | 3 | 1 | 1 | 5 | |
| • pre-programmed sets of preferences (weights) | 2 | 1 | 4 | 2 | 1 |
| • pre-programmed accident scenarios with suitable countermeasures | | | 5 | 3 | 2 |
| Were you provided with enough facts and details about the case Loviisa? | | 1 | 4 | 4 | 1 |

***Table VIII.*** *Answers to the questions about the decision analysis technique used in the first phase of the decision conferences.*

| **Decision Analysis Techniques** | ☹☹ | ☹ | 😐 | ☺ | ☺☺ |
|---|---|---|---|---|---|
| How appropriate do you feel that the use of a decision analysis approach is in this type of context? | 1 | 4 | 1 | 2 | 2 |
| How helpful was it to list all factors and attributes relevant to the decision? | | 2 | 1 | 4 | 2 |
| How satisfied were you with the final value hierarchy? | | 3 | 4 | 2 | |
| Did the use of a decision analysis technique make you consider more aspects of the problem than usual? | | 1 | 3 | 4 | 2 |
| Is it possible to describe a strategy’s impact on qualitative factors (e.g. on socio-psychological factors) in one phrase (e.g. from very negative to very positive)? | 4 | 3 | 2 | | |
| How appropriate do you feel the weighting of the attributes was? | 2 | 2 | 2 | 2 | |
| Did the analysis of the ranking of the strategies (resulting from the weighting) give you new insights into the problem? | 2 | 4 | 4 | | |
| How would you rate the impact the presence of a facilitator and analyst had on the discussion (intimidated - no effect - helped)? | 2 | | 1 | 4 | 3 |
| Could the conference have been held equally well without the help of the decision analysis technique? | 2 | 3 | 2 | 2 | |
| Would it have been enough to follow the international recommendations? | 1 | 3 | 2 | 2 | |
| How important is it to be able to explain and justify the decision afterwards? | | | | 1 | 8 |
| How much does this type of approach help to justify and explain the decision afterwards? | | 2 | 1 | 1 | 4 |
| Would you be willing to use this type of approach again? | | 1 | 2 | 1 | 4 |

To examine the successfulness of the decision conferences, it is beneficial to study how well the objectives of the first conference (see chapter 3.2.1) were met. The first objective, i.e., to define the factors important when deciding on countermeasures, was met. The preliminary value tree lists the wide range of attributes deliberated at the outset of the meetings. The final value tree contains attributes that were considered important when judging the different countermeasure strategies in the Loviisa case study and thus provided the basis for the decision conference. Nevertheless, the quality of the value trees needs to be further developed with respect to the definitions of their attributes. This is something to be done with the insight gained during the analysis.

The second objective, to define the intervention levels, was not met. Different intervention levels were discussed but the discussion mostly revolved around whether international recommendations should be followed or not. The timing and duration of the countermeasures were not touched upon.

All the decision-making issues mentioned in chapter 3.2.1 were discussed. A value tree was constructed and examined. The anchoring effect was noted and the feasibility of treating different population groups differently was briefly discussed. The question whether to use the *number of cancer cases* or the *number of cancer incidents* was also discussed. However, all these decision-making issues were only briefly considered, since only a few hours were spent on them. More exercises are thus needed.

In addition, some important notes were made during the meetings. Below is a list of the most relevant:

- Anchoring on the international recommendations prevailed, even after the participants were asked to ignore them.

- It is important to define precisely all the attributes used, otherwise misunderstandings will occur and valuable time will be wasted on explanations.

- There were concerns about including in the analysis non-quantifiable factors such as social or psychological ones. Giving weight to these attributes was considered questionable. Some participants saw no need for including such factors.

- If the treatment cost of cancers are included in the cost attribute, the cost and cancer incident attribute are no longer independent of each other.

- There was mistrust of the data calculated on some occasions, which indicates that there should be ways to verify the numbers (other than measurement data) in order to increase confidence in the results. Suggestions were made that it might be useful to include a number of benchmark cases in the software.

- It was also suggested that some facilitators should be trained to become familiar with radiation safety concepts and terminology, so that when an accident occurs there would always be a trained facilitator at hand. These facilitators should be professionals in decision analysis rather than experts in radiation protection.

- If a major city like Helsinki is affected by the accident and the number of cancer incidents or deaths is used, then the city becomes the focal point. This happens because there are so many more people living in Helsinki than elsewhere in Finland that even if they receive a much lower dose than others there will still be more incidents. Regarding this the cancer occurrence thematic was found to be very informative.

- The importance of informing the public correctly, a factor not included in the analysis, was emphasised several times.

- The decision-making process, when using a decision analysis approach, should be conducted in the same way as when no mathematical techniques are used. Some participants were not comfortable with the mathematical decision model, in particular in the early phase of an accident.

- Decision conferencing is certainly useful in the later phases of an accident, when there is time to model the situation. Then also different stakeholders will take part in the decision process. In contrast, the decision conferencing approach taken in the conferences in this study is meant to be adopted in the early phases of an accident. Since time is curtailed then, a common understanding and acceptance of the decision analysis procedures is a prerequisite.

## 2.3 Second Phase of the Decision Conferences: Uncertainties

### 2.3.1 Background

The second phase of the decision conferences ended with a meeting on 4th December. A preconference had been held one week earlier. This time the preconference was mostly a practice session and dealt with the same issues as the main meeting, however attended by different people. The lessons learnt from the preconference were used to improve the setting and the data used for the main meeting; thus slightly different accident scenario was also used.

The overriding objective of this conference was to study how uncertainties affect the process of decision-making and how they should be included in the analysis. Otherwise the objectives were the same as in the first decision conference. Furthermore, this time the goal was to perform a full MAUT analysis, or at least to demonstrate one.

The case used here included uncertainties, but only uncertainties about the release fractions. A release was assumed to happen definitely and it was assumed that the weather for the next few hours could be predicted. Furthermore, the containment event tree branch was identified and therefore the fission safety people were able to give probability distributions on release fractions. Based on these release fractions the probability distributions of the impacts of the accident were calculated. The time of the meeting was set when the release has just started and measurement data were about to come in. Uncertainties in the dispersion calculation were not included in the impact distributions.

For the purpose of the analysis it was assumed that a hypothetical core-damaging and containment leak accident had occurred at the Olkiluoto nuclear power plant in Finland, leading to contamination of the environment. The chosen time of the accident was the middle of August. The probability of occurrence of such a containment failure accident leading to a significant release in real life is estimated to be less than one in 1,000,000 per reactor-year for this NPP.

The release scenarios for the Olkiluoto nuclear power plant were based on containment failure classification. There are several possible containment event tree branches in each containment failure group and the release fractions given in Table IX are due to one possible branch in the early containment failure group. These values were based on an assessment of the NPP by STUK's nuclear safety experts. The progress of the accident was described as follows:

‘The initiator is loss of external grid due to a minor earth shaking. The same shaking of the earth breaks the backup battery cabinets, since the batteries are very heavy and the design of the cabinets did not take earth shaking into account[2].

The automatic overpressure protection of the reactor is successful and the hydraulic SCRAM succeeds. The containment is successfully isolated. The overpressure protection valves close successfully. During the next 45 minutes, the auxiliary feedwater cannot be started and the manual pressure reduction of the reactor fails. Thus the pressure cannot be lowered to the operating range of the low pressure emergency cooling system.

50 minutes after the initiator, the core starts to melt under high pressure. The pressure reduction of the vessel can be recovered before 90 minutes, so the pressure of the vessel can be lowered. The core cooling systems cannot be recovered before the end of the recriticality time window, so there is no recriticality in the core. The flooding of the lower drywell (pedestal) is successfully done before the vessel breach.

After 2 hours, the vessel breaches into water-filled containment and the containment fails due to a corium spray hitting penetrations above the water level. Thus, there is a direct path from the containment atmosphere to the reactor building, bypassing the filter and stack. The reactor building remains intact, and since it is very large, some deposition occurs also in the reactor building. The corium remains under water.’ (Niemelä, 1997)

In this accident up to few tens’ percent of the fission products were assumed to have been released into the environment (Table IX). The release began two hours after shutdown and lasted for 12 hours. The release rate was not constant, i.e., the initial intense release went down roughly exponentially in 12 hours. The effective release height was 50 m, which corresponded roughly to an initial sensible-heat release rate of a few megawatts (the venting occurs at a height of 10 m). Figure 11 shows the thematic map of the estimated effective doses when the release scenario would be the 50% fractile.

### 2.3.2 Preconference

A week before the main meeting a preconference was held with four experts from STUK. The session was a practice session, i.e., the same issues were dealt with as one week later in the main meeting, although this session did not proceed as far.

First, the accident and the uncertainties involved were explained and discussed. Then the value tree constructed in the first phase of the decision conferences (see Figure 6) was shown and four possible countermeasure strategies were presented and discussed.

Because the impacts of this accident were not as severe as in the Loviisa case, the participants felt that the value tree needed changing. The attributes *deterministic effects, non-radiation,* and *technical feasibility* were discarded and instead a new attribute called *futility* was added.

[2] Currently TVO is planning modifications to these cabinets.

***Table IX.*** *The Release fractions assumed for the hypothetical accident, Olkiluoto, 'early containment failure'. The release fractions are 5%, 50% and 95% fractiles of the containment failure groups cumulative distribution.*

| **Nuclide group** | **Release fraction** | | |
|---|---|---|---|
| | **5% fractile** | **50% fractile** | **95% fractile** |
| Noble gases | $4.7 \cdot 10^{-1}$ | $4.9 \cdot 10^{-1}$ | $5.1 \cdot 10^{-1}$ |
| Iodine total | $2.1 \cdot 10^{-4}$ | $1.2 \cdot 10^{-2}$ | $1.3 \cdot 10^{-1}$ |
| Alkaline-group (Cs, Rb) | $2.0 \cdot 10^{-4}$ | $9.2 \cdot 10^{-3}$ | $1.1 \cdot 10^{-1}$ |
| Tellurium-group (Te, Se, Sb) | $2.0 \cdot 10^{-5}$ | $6.1 \cdot 10^{-3}$ | $9.2 \cdot 10^{-2}$ |
| Alkaline earth-group (Sr, Ba) | $3.4 \cdot 10^{-6}$ | $3.1 \cdot 10^{-4}$ | $3.1 \cdot 10^{-2}$ |
| Ruthenium-group (Ru, Mo, Tc) | $1.1 \cdot 10^{-7}$ | $3.7 \cdot 10^{-6}$ | $1.6 \cdot 10^{-3}$ |
| Lanthanide-group La, Nb, Zr, Cm, Ce, Nd, Pm, Sm, Eu, Pu, refr. Ox. Nb, Zr) | $4.6 \cdot 10^{-8}$ | $1.2 \cdot 10^{-5}$ | $3.1 \cdot 10^{-3}$ |

This attribute was thought to address the issue of "unnecessarily doing too much". Furthermore, the attribute *socio-psychological factors* was re-divided into *positive effects* and *negative effects,* which were felt to represent better the different socio-psychological impacts of the countermeasure strategies. The modified value tree is to be found in Figure 12.

As possible protective actions only the issuing of iodine tablets and sheltering were considered in the preconferences. It was assumed that the necessary immediate actions, such as sheltering in the near vicinity of the power plant and Rauma, had already been taken. The four strategies discussed were:

- No further action in addition to what had already been taken.
- Limited action - issue iodine tablets and implement sheltering in the nearby areas downwind from Rauma.
- Medium action - include Turku in the areas where intake of iodine tablets and sheltering are implemented.
- Wide action - issue iodine tablets and recommend sheltering all the way to Tampere.

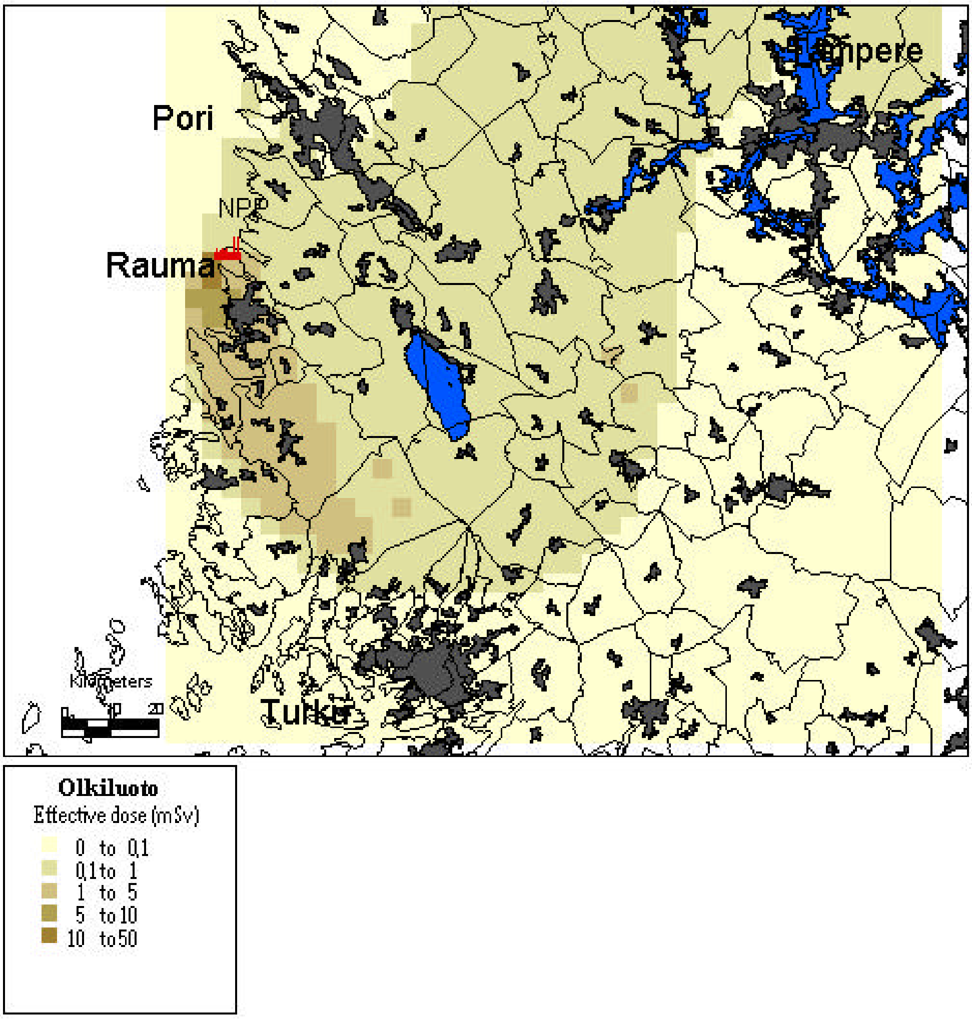



***Figure 11.*** *Spatial effective dose distribution due to the 50% fractile release scenario. The towns to the South of the plant at Olkiluoto are Rauma (10 km away) and Turku (100 km away); in the upper right corner is Tampere.*

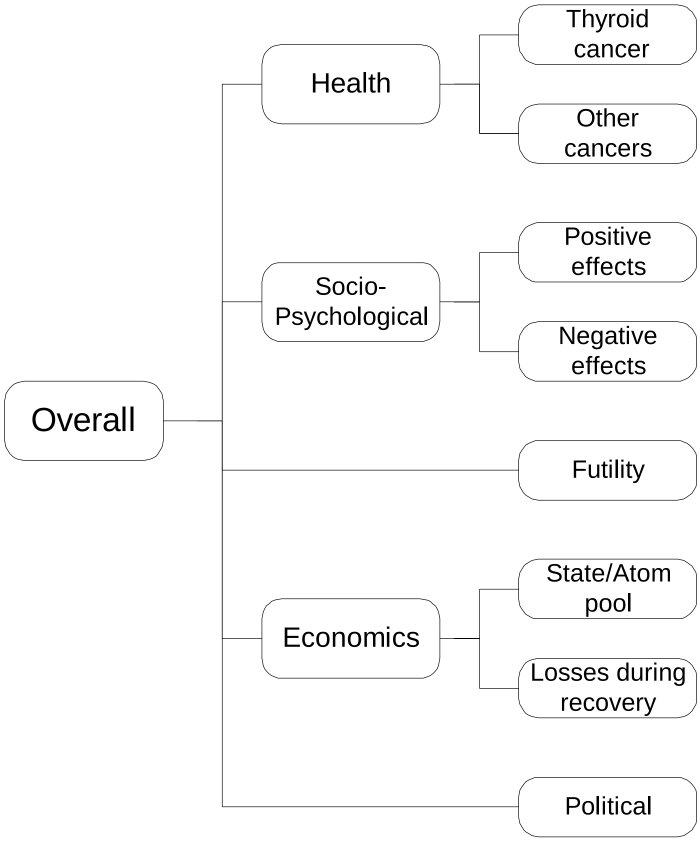



***Figure 12.*** *Value tree used in the preconference in the second phase of the decision conferences.*

The impacts of the four strategies on the different attributes were discussed and some of them also elicited from the participants. However, elicitation proved very difficult and time also ran out, so the elicitation process was not finished.

### 2.3.3 Finnish Decision Conference - Case: Olkiluoto

The second Finnish Decision Conference was held on 4th December at STUK. Six people participated in the meeting: four people from STUK, two persons from Finnish power companies and one retired STUK employee.

The role of the group was agreed to be that of the radiation protection group at STUK. That is, the group's task was to assess the situation and give advice to the management group responsible for the co-ordination of the activities at STUK as to what countermeasure strategy to use. The management group was expected to make a suggestion on the best course of action within an hour, which meant that the group had a tight schedule to meet. However, as the meeting was part of the RODOS project, certain time-outs were taken to discuss or explain important issues of concern to the overall RODOS project.

The value tree built in the preconference (see Figure 12) was demonstrated and a new modified version was also shown. The new value tree was otherwise the same as the previous one, but the attributes *futility* and *losses during recovery* had been removed. Also, the attribute *economics/state and Atom pool* was changed to simply *costs* and the attribute *political* was changed to *political cost*. The final value tree is found in Figure 13. The participants agreed that the new value tree was better suited for this case and would be used in the analysis.

The attributes were discussed and their units in particular raised comments. The problem whether to use cancer deaths or cancer incidents as a unit was ventilated once again, and it was decided to use cancer incidents. Especially for thyroid cancer it is important to know the number of incidents. The attributes and their respective description, unit of measurement and range are given in Table X.

***Table X.*** *The attributes used in the second phase of the decision conferences and their respective description, unit of measurement and range.*

| Attribute | Description | Unit and range |
|---|---|---|
| **Health** | | |
| Thyroid cancer | thyroid cancer in children | no of cancer incidents (0-250) |
| Other cancer | other types of cancers | no of cancer incidents (0-320) |
| **Socio-Psychological** | health or safety related | |
| Positive effects | reassurance | no change - very positive (0-100, relative scale) |
| Negative effects | disturbances in social relations and lifestyle | no change - very negative (0-100, relative scale) |
| **Costs** | direct costs, compensation, protection | 0 - 184 MECU |
| Political costs | public confidence in the authorities, national security, international confi dence in Finland and Finnish products | no change - very negative (0-100, relative scale) |

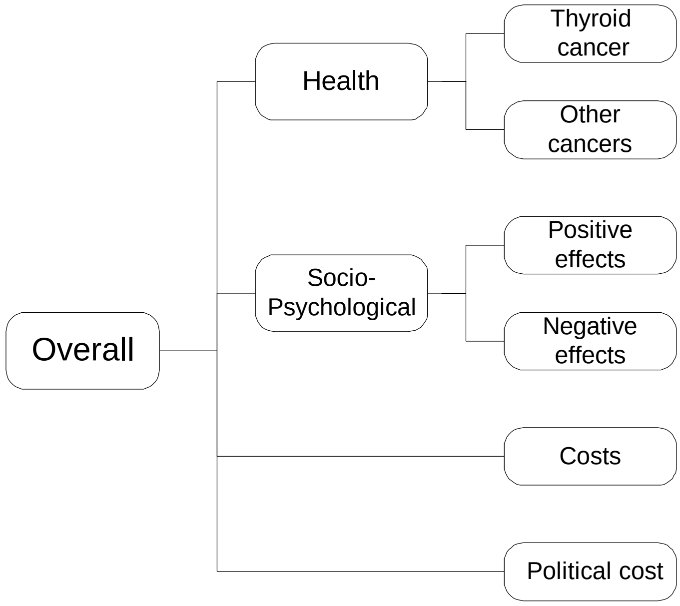



***Figure 13.*** *Final value tree used in the second phase of the decision conferences.*

Five different strategies were constructed and analysed:

- Strategy 0: Do nothing at all.
- Strategy 1: Intake of iodine tablets and sheltering in Rauma - a city of 30,000 inhabitants within the 20 km zone.
- Strategy 2: Implement sheltering in Rauma and the closest areas around the city. Intake of iodine tablets almost all the way down to Turku, i.e., 100 km away from the site.
- Strategy 3: Implement sheltering in the same areas as in Strategy 2, but intake of iodine tablets in all areas affected by the accident, i.e., including both the cities of Turku and Tampere, for example.
- Strategy 4: Evacuate Rauma after the cloud has passed the area. Sheltering was implemented and iodine tablets taken during the plume passage.

The number of people affected and the size of the area where the countermeasures would be taken, have been computed by means of EMERSIM and the results are given in Table XI.
The impact of each strategy on the different attributes was discussed and elicited. The RODOS software calculated the economic costs and the number of cancer deaths, which was then translated into cancer incidents. The participants supplied the impacts for the non-quantifiable factors. All three fractiles were considered separately. The resulting impacts can be seen in Table XII.

Because uncertainties were included this time, and the SMART and Trade-off techniques (see below) were to be used for the weighting, the shape of the utility functions of the different attributes needed to be assessed (see, e.g., French 1988 for further information on utility theory). The participants were asked to answer lottery questions of the type that can be seen below and in Figure 14. The answers were given by individual participants, but because they were given openly and the whole group discussed them, the resulting utility functions were used as the group's opinion.

***Table XI.*** *Number of people and size of area affected by the countermeasure strategies in the second phase of the decision conferences.*

| **Countermeasure Strategy** | **Area [km$^2$]** | **No. of People** |
|---|---|---|
| Strategy 0: | | |
| Sheltering | 0 | 0 |
| Iodine Prophylaxis | 0 | 0 |
| Evacuation | 0 | 0 |
| Strategy 1: | | |
| Sheltering for 12 hours | 560 | 40,600 |
| Iodine Prophylaxis | 560 | 40,600 |
| Evacuation | 0 | 0 |
| Strategy 2 | | |
| Sheltering for 12 hours | 1150 | 56,200 |
| Iodine Prophylaxis | 3040 | 88,500 |
| Evacuation | 0 | 0 |
| Strategy 3 | | |
| Sheltering for 12 hours | 1150 | 56,200 |
| Iodine Prophylaxis | 26900 | 1,023,000 |
| Evacuation | 0 | 0 |
| Strategy 4: | | |
| Sheltering for 8 hours | 560 | 40,600 |
| Iodine Prophylaxis | 560 | 40,600 |
| Evacuation | 560 | 40,600 |

*Lottery question:*
*Please select the number of cancer incidents (L) that would make you indifferent if you have to choose between having that number for sure and a fifty-fifty chance of having either 250 cancer incidents or 0 incidents.*

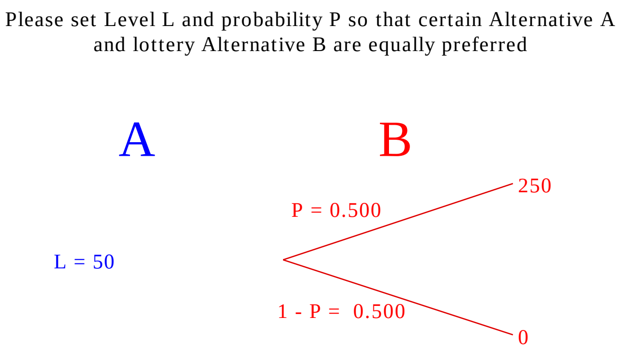



***Figure 14**. Lottery question used in the second phase of the decision conferences.*

The above type of question is not easy to understand. To provide a further explanation of what was asked, the following example was given. "Imagine that you have two methods of treating the patients. An old and well-known method that you know will help some people, but still result in exactly 50 incidents (alternative A). Then there is a new, advanced method (alternative B) which, if it works, will cure all patients. However, the method has not been tested and there is only a fifty-fifty chance that it will work. If it does not work, then you will have 250 incidents. Which method do you prefer?"

Only the utility functions for the two cancer attributes and the costs attribute were given non-linear forms by participants, the rest were left linear. See Figure 15 (a-f) for the shapes of the utility functions. From the utility function for the *costs* attribute it can be seen that the participants did not give much thought to money. It is only after the costs exceed about 134 MECU that there is any significant decrease in the utility. When it comes to cancer, the participants seemed to be risk seeking, i.e., they would rather take a risky option with the possibility of avoiding cancer totally than the sure option of having some cancer incidents.

***Table XII.*** *The impacts of each strategy on the different attributes in the second phase of the decision conferences. All three fractiles are considered.*

| **Attribute** | **Unit** | | **Strategy 0** | **Strategy 1** | **Strategy 2** | **Strategy 3** | **Strategy 4** |
|---|---|---|---|---|---|---|---|
| **Health** | | | | | | | |
| Thyroid cancer | number of | 5% | 0 | 0 | 0 | 0 | 0 |
| | cancer | 50% | 20 | 5 | 2 | 2 | 4 |
| | incidents | 95% | 240 | 50 | 20 | 20 | 40 |
| Other cancers | number of | 5% | 0 | 0 | 0 | 0 | 0 |
| | cancer | 50% | 22 | 20 | 20 | 20 | 12 |
| | incidents | 95% | 320 | 286 | 288 | 286 | 204 |
| **Socio-Psychological** | | | | | | | |
| Positive effects | no change - | 5% | 0 | 100 | 10 | 10 | 0 |
| | very positive | 50% | 0 | 75 | 50 | 45 | 40 |
| | (0 - 100) | 95% | 0 | 50 | 90 | 80 | 80 |
| Negative effects | no change - | 5% | 40 | 0 | 90 | 80 | 50 |
| | very negative | 50% | 70 | 40 | 50 | 45 | 35 |
| | (0 - 100) | 95% | 100 | 80 | 10 | 10 | 20 |
| **Costs** | MECU | 5% | 0 | 1.6 | 2.2 | 2.2 | 160.3 |
| | MECU | 50% | 2.0 | 3.1 | 3.8 | 3.8 | 160.8 |
| | MECU | 95% | 27.7 | 23.9 | 24.3 | 24.1 | 176.3 |
| **Political cost** | no change - | 5% | 30 | 0 | 0 | 20 | 80 |
| | very negative | 50% | 65 | 40 | 40 | 30 | 50 |
| | (0 - 100) | 95% | 100 | 80 | 80 | 40 | 20 |

The weights for the attributes were elicited both with the SMART technique and with the Trade-off method. (A trade-off is a pair of equally preferred hypothetical alternatives that differ on only two attributes: alternative A has a more preferred level on attribute 1 and a less preferred level on attribute 2 while alternative B has a less preferred level on attribute 1 and a more preferred level on attribute 2. The levels of the attributes are set so that a change in attribute 1 just compensates for a corresponding change in attribute 2.) Typical questions were: how much are you prepared to pay in order to avert 320 cancers? How many thyroid cancers are you prepared to accept in order to avert 320 other cancers? How positive must the socio-psychological effects be in order to compensate for all their negative effects?

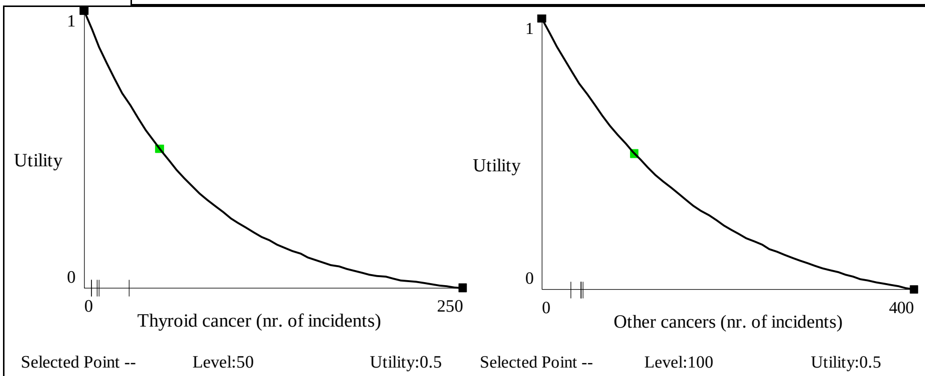
The resulting weights from both methods are set out in Table XIII. and the resulting rankings of the strategies are set out in Figures 16 and 17. The two methods produced quite different sets of weights and thus also different rankings. This might be due to the fact that the preferences were given quite rapidly and not too much deliberation was put into the process. However, Strategy 3 is the best option in both rankings.

Some sensitivity analyses were also performed on rankings obtained by either method. See Figure 18 for examples. From the figure it can be seen that both results are quite robust on the *socio-psychological* attribute. However, since very little weight was put on this attribute, very little can be deduced.

Looking at the results, an observation can be made. The impact on cancer and costs in Table XII is in many cases the same regardless of what strategy is chosen: strategy 0 is worst in terms of thyroid cancer and strategy 4 in terms of costs, but the remaining strategies score about the same on the cost and cancer attributes (see Figures 16 and 17). Consequently, their ranking will be solely based on how well they score on the other attributes, e.g., political costs. Nevertheless, most of the discussion emphasised the cancer attribute and it also received a lot of weight in the analyses. But how is it that the cost and cancer attributes cannot discriminate between strategies 1, 2 and 3? The reason for this finding is, on the one hand, the sparse population density and hence very few cancer cases in the area where the plume hits after Rauma and, on the other hand, the cheapness of iodine prophylaxis: neither by increasing the shelter area nor the stable iodine target group is it possible to reduce the few cancer incidents expected within this scattered settlement area. And no additional costs incur in our model even though iodine is administered, instead of to 40,000 people (strategy 1), to over 1 million (strategy 3).

***Table XIII.*** *The weights given in the second phase of the decision conferences. The values given in parenthesis and in the last column refer to an elicitation where only the worst scenario was considered (see later in the text).*

| **Attribute** | **Worst Level** | **Best Level** | **SMART** | **Trade-off** | **SMART 95%** |
|---|---|---|---|---|---|
| Thyroid cancer | 240 | 0 (20) | 0.328 | 0.210 | 0.400 |
| Other cancers | 320 | 0 (204) | 0.262 | 0.105 | 0.120 |
| Positive effects | 0 | 100 | 0.016 | 0.030 | 0.040 |
| Negative effects | 100 | 0 | 0.098 | 0.101 | 0.080 |
| Costs | 180 | 0 (30) | 0.033 | 0.050 | 0.040 |
| Political cost | 100 | 0 | 0.262 | 0.504 | 0.320 |




*a) Thyroid cancer* *b) Other cancers*

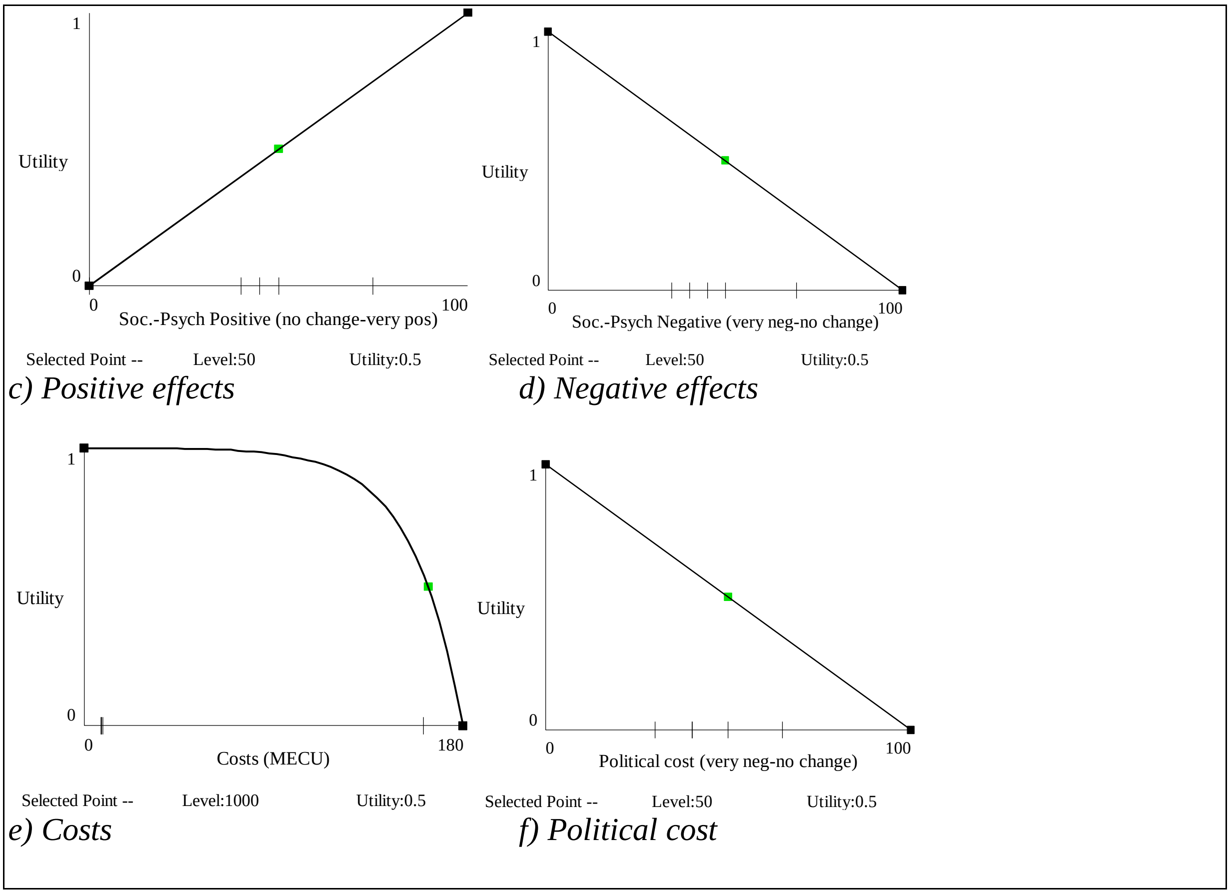



***Figure 15.*** *Utility functions for the different attributes in the second phase of the decision conferences.*

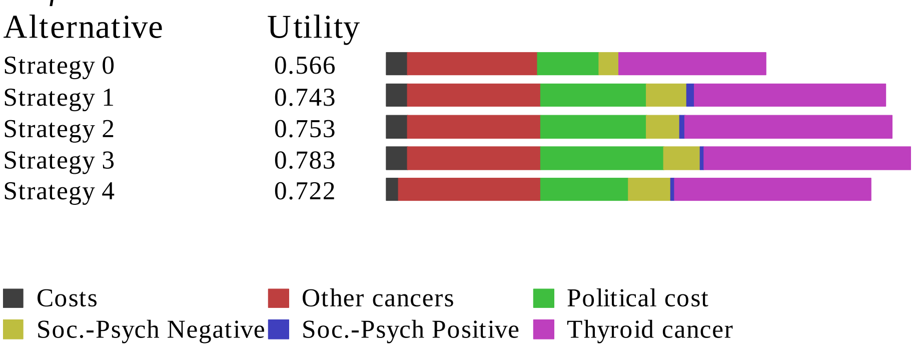



***Figure 16.*** *Ranking of strategies with SMART - second phase of the decision conferences.*

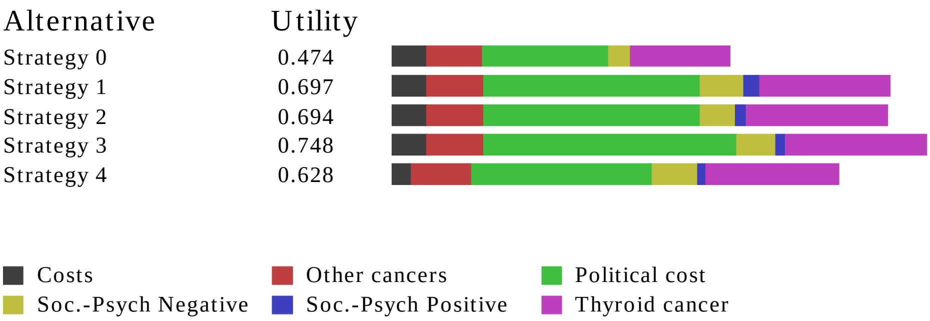



***Figure 17.*** *Ranking of strategies with Trade-off – second phase of the decision conferences.*

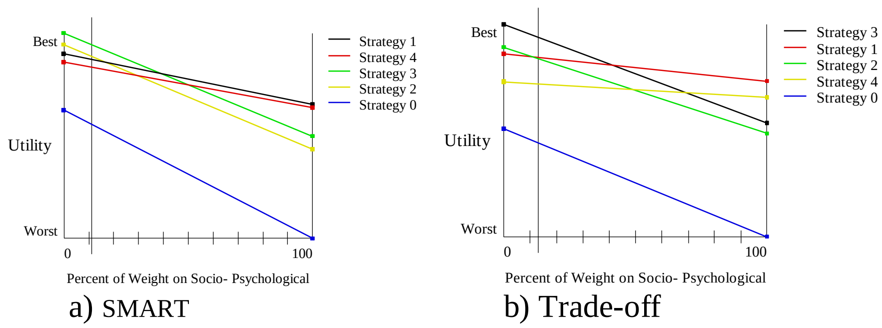



***Figure 18.*** *Sensitivity analyses performed in the second decision conference.*

The above analyses had been done on the whole probability distributions. Next it was examined how the results would change when the participants focused only on the worst scenario, i.e., the one corresponding to the 95% fractile. N.B., the actual radiological situation is less severe than that with a probability of 95%. This time the weights were given only with the SMART technique. The weights for the 95% fractile are also given in Table XIII and the resulting ranking of the strategies is to be seen in Figure 19. The scale of interventions increases obviously.

An example of the sensitivity analyses performed on the 95% fractile case is found in Figure 20.

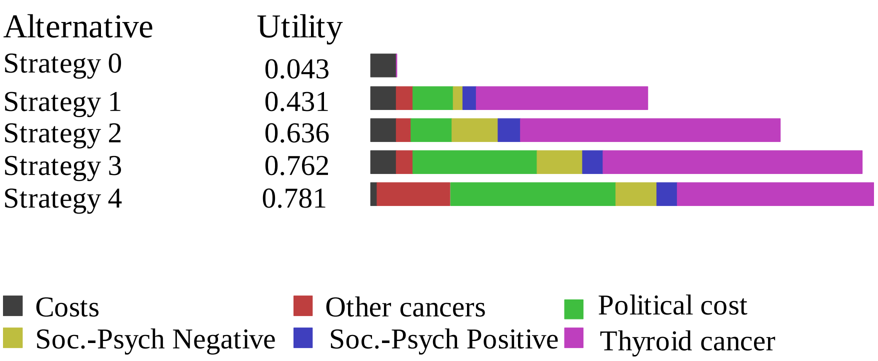


*Figure 19. Ranking of strategies for the 95% fractile case - second phase of the decision conferences.*

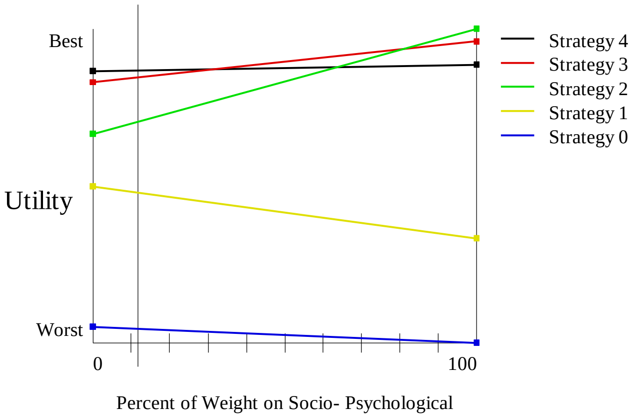



***Figure 20**. Sensitivity analysis - 95% fractile*

### 2.3.4 Questionnaire

A questionnaire was given to all participants at the end of the meeting. Three of the six participants (50%) returned the questionnaire and in addition two members working on the RODOS project answered the questions. The answers to the questions about the decision conference, including uncertainties and RODOS in general are given in Table XIV.

It can be seen from the answers that the participants were somewhat divided in their opinions on most issues. Some were in slight disagreement and some were in slight agreement. However, in general the people working on the project took a more positive attitude toward decision conferencing and RODOS than the participants.

In the questionnaire the participants were also asked to give points to the attributes using the SMART technique. In Table XV are the points given and the resulting weights. As can be seen from the table, different people emphasised different attributes and thus the weights differ substantially between different persons. But interestingly enough, the rankings of the countermeasure strategies are still about the same (see Table XVI). Everybody has strategy 3 as the best alternative, strategies 1 or 2 as the next choice and strategies 0 and 4 as the worst.

When asked which nuclides are the most important to get correct information about, the participants all answered that iodine was the most important. Cs, Kr, Xe and the other noble gases were also considered important. When asked which fractiles they would like to see, the answers were either 5%, 50%, and 95% or 1% 50% and 99%, i.e., evenly distributed around the median. Judging by the emphasis placed on the fractiles during the session, one would have expected a more skewed distribution, for example 5%, 50%, 90%, and 99%.

### 2.3.5 Summary and Conclusions of the Second Phase

The second phase of the decision conferences dealt with the issue of how to include uncertainties in the analyses. The accident scenario simulated in this conference included uncertainties about how severe the accident actually was. Therefore the impacts of the 5%, 50%, and 95% fractiles of the release fractions were calculated and presented to the participants. The countermeasure strategibes considered were also given and the value tree used was a modified version of the value tree developed in the first phase of decision conferencing. Thus the participants had all the data they needed and were left with the task of incorporating the uncertainties in their preferences.

***Table XIV***. *Answers to the questionnaire after the second phase of the decision conferences.*

| **Decision Conference and RODOS** | ☹☹ | ☹ | 😐 | ☺ | ☺☺ |
|---|---|---|---|---|---|
| When looking at the maps, how much did you consider the cut off values involved (versus just looking at the coloured areas)? | | | 2 | 1 | 2 |
| How much did you consider the probabilities involved, i.e. their numerical values ? | | 1 | 1 | 3 | |
| How much would your opinions have changed if the same scenarios had been used, but the fractiles had been 25%, 50%, 75%? | 1 | | 2 | 2 | |
| How much would your opinions have changed if the same scenarios had been used, but the fractiles had been 1%, 50%, 99%? | 1 | | 4 | | |
| These types of exercise are important. | | 1 | | 3 | 1 |
| All in all, how would you rate the exercise? | | 1 | 1 | 3 | |
| What type of data on the uncertainties should RODOS provide: | | | | | |
| • point estimates (like the scenarios in this exercise)? | | 1 | 1 | 2 | 1 |
| • probability distributions for the different factors (nuclides, doses, etc.)? | | 2 | | 2 | 1 |
| • probability distributions for the different impacts (cancers, costs, etc.)? | | 2 | | 2 | 1 |
| RODOS should also estimate the impact on qualitative factors, for example on political cost or socio-psychological impacts. | | 1 | 1 | 1 | 2 |
| It is important to know whether an area is rural or urban when considering what countermeasures to take. | 1 | | | 3 | 1 |
| A multi-criteria decision-making approach is useful in this type of context. | | | 1 | 4 | |
| It is easy to give preference statements about value trade-offs involving both monetary and health related attributes. | 1 | 2 | | 1 | 1 |
| Better decisions are made when probability distributions are considered than when only discrete scenarios are considered. | | 2 | 1 | 2 | |
| It is easy to understand probability distributions. | 1 | 2 | | 2 | |
| How easy did you feel it was to give the points with SMART? | 1 | 1 | 1 | 1 | 1 |

***Table XV.*** *Weighting of the attributes with the SMART technique by three participants in the second decision conference and two people working on the RODOS project. Points given and the resulting weights.*

| SMART | DM 1 | | DM 2 | | DM 3 | | RODOS 1 | | RODOS 2 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Thyroid cancer (0 to 240 cancer incidents) | 100 | 0.323 | 15 | 0.091 | 100 | 0.444. | 100 | 0.238 | 90 | 0.295 |
| Other cancers (0 to 320 cancer incidents) | 60 | 0.194 | 100 | 0.606 | 50 | 0.222 | 100 | 0.238 | 95 | 0.311 |
| Soc.-psych Positive (0 to 100 relative) | 20 | 0.065 | 0 | 0 | 5 | 0.022 | 20 | 0.048 | 10 | 0.033 |
| Soc.-psych Negative (0 to 100 relative) | 40 | 0.129 | 0 | 0 | 10 | 0.044 | 40 | 0.095 | 10 | 0.033 |
| Costs (0 to 180 MECU) | 10 | 0.032 | 50 | 0.303 | 10 | 0.044 | 100 | 0.238 | 100 | 0.328 |
| Political cost (0 to 100 relative) | 80 | 0.291 | 0 | 0 | 50 | 0.222 | 60 | 0.143 | 0 | 0 |

Utility functions were constructed to handle the uncertainties, and both the SMART method and the Trade-off method were used to elicit preferences. Sensitivity analyses were then performed to study the robustness of the rankings. The 95% fractile was also considered separately to study whether that would affect the outcome, which it did. A more severe scenario demands tougher countermeasures, so it would seem.

The utility functions elicited for the two cancer attributes encode a risk seeking attitude: the participants preferred a risky option with the possibility of avoiding cancer totally to an option of having some cancers for certain. However, this attitude has to be questioned, and it is, for example, contrasted by French and Papamichail (1997) when they state ”that the decision makers should be risk averse in emergency management situations”. The particular lottery offered to the participants when eliciting these utility functions may well have left its mark on their shape. A formulation of the lottery closer to the case would have been preferable. For example: a release is due to happen, but you do not know when. All you have is an assessment of the probability that the release happens while evacuation is going to take place. You have two options: shelter and accept 160 cancers for sure or take the risk and evacuate. If you have the people evacuated before the start of the release

***Table XVI.*** *Ranking and overall score of countermeasure strategies in the second decision conference.*

| **Score and ranking** | **DM1** | | **DM2** | | **DM3** | | **RODOS 1** | | **RODOS 2** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Strategy 0 | 0.519 | 5 | 0.812 | 4 | 0.595 | 5 | 0.651 | 5 | 0.764 | 4 |
| Strategy 1 | 0.738 | 2 | 0.838 | 3 | 0.773 | 3 | 0.802 | 2 | 0.862 | 3 |
| Strategy 2 | 0.732 | 3 | 0.845 | 1 | 0.796 | 2 | 0.798 | 3 | 0.872 | 1 |
| Strategy 3 | 0.762 | 1 | 0.845 | 1 | 0.819 | 1 | 0.815 | 1 | 0.872 | 1 |
| Strategy 4 | 0.699 | 4 | 0.735 | 5 | 0.747 | 4 | 0.686 | 4 | 0.727 | 5 |

you avoid all cancers. However, if not, you will have to accept 320 cancers. What odds do you need as a minimum for deciding on evacuation? Or in other words, what probability of the release makes you indifferent between these two options?

All in all, the main objective of the conferences was to study the use of uncertainties. Some important notes on including uncertainties, decision conferencing and the RODOS project in general were made during the sessions. The most important ones are listed below:

- It is easier to give weights with SMART than with Trade-off, because you can see where the weights come from (might also mean greater commitment). This ease might partly be due to the fact that you can give the points without considering the actual ranges of attributes. In that case the results can be questioned.

- The attributes need to be clearly specified. Especially the more intangible attributes like *socio-psychological* factors or *political cost* need closer specification. The participants had difficulties in understanding and interpreting them in the same way. How can they rate something they do not understand? In summary, attributes need to be operational in the sense that they have to be specific enough in order for the participants to be able to evaluate and compare them for the different strategies.

- It is a very vulnerable matter not to be on the safe side. However, if there is no understanding of how to express one's preferences over values and how to make choices in risky situations, it is also difficult to say how precautions the actions should be (safety margin). This might have resulted in the attributes *political cost* or *futility*, which might have aimed to express the aspiration of safety.

- Including political cost in the analysis can cause problems, if each group does so just by adding their own safety margin onto the results obtained from another group. It is preferable to tell explicitly what factors have been included. Applying decision analysis techniques can improve the transparency of the decision-making process.

- The participants more or less ignored the 5% fractile and mostly looked at the 50% and 95% fractiles. What if the highest fractile had been 99% or 75%? It seems to be difficult to explain why to use utility analysis, i.e., how to benefit from probabilities in a decision when facing uncertainties.

- Also, the use of thematic maps could mislead people. The choice of cut off values can change the impression people obtain of the accident. The areas left white on the map are not necessarily completely free of radiation. Even experts might be wrong and have false impressions. It was demonstrated during the sessions that everybody thought that the occurrence of the cancers was more evenly spread than it actually was.

- Issuing iodine tablets is a cheap countermeasure, which means that the tablets could be given to everybody and everywhere just to be on the safe side. The psychological effects and possible medical side effects need to be remembered, however. The participants wanted to issue iodine tablets, even when it was indicated that it would have no effect, i.e. that it would not decrease the number of cancer incidents.

# 3. DISCUSSION

## 3.1. The Finnish Decision Conferences

### 3.1.1 The Conferences

The series of decision conferences organised in Finland in the autumn of 1997 and described in Chapter 3 produced many new ideas and insights that will be further discussed in this chapter.

The cases used in the conferences were simulated nuclear accidents. The setting and description of both accident scenarios were detailed and realistic and the participants actual people responsible for that part of the decision-making. That is, the whole decision-making situation can be said to have been quite close to a real-life situation. It can be concluded that the experiences and results obtained from these two series of decision conferences have a high degree of reliability and that the RODOS project should be able to benefit from these findings.

At the same time it should be remembered that some simplifications were made in the process. For example, only a very limited number of possible countermeasure strategies were used, which limited the usefulness of any decision aiding. In the future, a wider span of good options should be generated, e.g., by ‘screening strategies’ (a feature planned for RODOS), in order to be able to test whether and how the decision-makers benefit from the decision analysis methods. One possible way would be to iterate: first give the type of strategies that were used in these conferences, but then, when it becomes clear which strategies are preferred, develop a new set of alternative strategies in that region.

One aspect that enhanced the real-life impression was the time limit imposed on the participants. A decision had to be made within a certain time. This resulted in the participants having very little time really to think about the issues and thus simulated a real-life accident, but at the same time it also had a negative effect on the theoretical research. Because of time pressure some choices were made by the facilitator and the choices made by the participants are not necessary their true or best ones. Therefore, it is difficult to say what the participants really would have done or wanted. However, in a real accident the situation would be the same. The spontaneous type of decision conferencing used in the conferences is one way to deal with the time pressures. A decision analysis interviewing technique could perhaps also be used quickly to elicit the decision-makers' opinions and then apply them to the decision model the facilitator or group leader has constructed.

A general finding from the conferences was that it is very useful to have these types of conferences. They are rare and many issues need to be discussed. Furthermore, constructing a large value tree like the one in Figure 4 helps the decision-maker to consider all relevant factors. Thus it becomes easier to focus on the most important ones and later also explain what has been done and why it was done. A generic value tree could be pre-programmed into RODOS: the decision-makers could examine the tree, pick the relevant attributes, and then continue from there, thus saving time.

Throughout the conferences a lot of time was spent on defining factors and wordings. There is a clear need to define the attributes in advance so that the persons involved understand their meaning. Below is given a list of attributes and their definitions deliberated upon by the authors with the insight gained during the meetings:

- *Collective dose to the public.* Stochastic health effects are likely to occur if large population groups are exposed to radiation, even though the individual doses were quite small. This attribute could be measured as projected collective dose to the public (manSv). An alternative measure would be the *number of cancer incidents.*

- *Individual dose to the public.* Some members of the public might be at higher stochastic risk or at risk of incurring deterministic effects. Their risk has to be considered individually and be measured by the individual dose (mSv).

- *Number of thyroid cancers in children.* Number of incidents in children.

- *Statistical non-radiation fatalities.* Number of statistical fatalities due to reduced health care, a deterioration in nutrition etc.

- *Individual non-radiation fatalities*. The number of people that suffer death in the course of taking countermeasures.

- *Dose to the workers.* Projected individual dose received by the workers carrying out early emergency actions (mSv).

- *Social disruption.* Disruptions in the social network, e.g., when evacuation or relocation is taken. Direct rating.

- *Anxiety of the population.* A majority of the persons living in the contaminated area may show varying degrees of stress reactions in response to an accident. But stress may also be introduced by the protective actions. The severity of an accident will be perceived through the protective measures taken. 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. Direct rating.

- *Anxiety of the workers*. Emergency actions will cause stress among workers who are implementing them. Direct rating.

- *Feasibility (in relation to defined quality or quantity)*. This attribute is in many cases a constraint preventing the implementation of an action. However, in some cases actions may differ in feasibility, e.g., sheltering and evacuation in cold weather conditions. Direct rating or other depending on case.

- *Monetary Costs.* The sum of direct and indirect costs of protective actions. Cancer treatment costs and losses to GDB caused by fatalities should not be included in this attribute in order to avoid double counting, i.e., not to convert cancers into costs. Monetary unit.

An attempt was made to define the attribute *political costs.* This attribute has to be better defined in order not to overlap with health-related obligations or social-psychological concerns of a decision-maker. A proper definition is important as the expression 'political costs' may mean different things at different decision-making levels.

Some issues were not included in the analysis or their impacts were not clear. Many times it was pointed out that the way the public is informed about the accident and the countermeasures taken are crucial. The people's reactions depend on what information they are given and how they interpret the situation. In addition, what countermeasures are implemented and how successfully also depends on factors which are not under the control of decision makers.

There should be a clear understanding on the countermeasures. Issuing iodine tablets was considered, but to whom? Can the tablets be taken only by children and will the adults comply with this? Furthermore, in Finland residential units are obliged to keep iodine tablets and small households are encouraged to purchase tablets. In a real situation, however, not all people may find them and the effectiveness of iodine prophylaxis could therefore be quite low. Also, other countermeasures need further examination in terms of their feasibility.

Finally, it should be mentioned that this type of setting assumes a single decision point. In reality, as was pointed out, the decisions could be made very well in a sequential manner. For example, first warn the public, then wait to discover how serious the accident is, and then, if necessary, employ stricter countermeasures. This type of approach was not allowed here, but should be considered in the future, when that possibility is included in the RODOS software.

All in all, many new insights were obtained from these conferences and, although much still remains to be done, the conferences were successful.

### 3.1.2 Decision Analysis

Different types of decision analysis techniques were used and experimented with during the decision conferences, for example, the SMART, SMARTER and Trade-off elicitation techniques. However, no detailed comparative testing was done between these methods and thus the possibility of procedural effects on the results should be kept in mind (see e.g. Pöyhönen and Hämäläinen, 1997).

Brainstorming and a faster type of decision conferencing were also used. The general impression from the conferences is that the decision-makers were not very familiar with this type of formal approach. Some progress was made, but more training is needed. Some participants did not feel comfortable with the modelling tools and many had problems in understanding the procedures. At this point we should remember that only a few hours were spent on the issues. However, the fact that progress was made even during this short period of time is quite encouraging.

The value tree was fairly easily constructed. An agreement was quickly reached on the factors to be included and on those to be eliminated. The preliminary value tree acted as a guide for finding a suitable final version. However, when comparing the value trees used in the different exercises, it can be seen that they changed from exercise to exercise. This is only partly due to the fact that different value trees are needed for different scenarios. It is also an indication that the choice of attributes was not always obvious. More research is needed to find out what attributes to include and how a generic tree could be constructed. At this point it should be remembered that the format of the value tree can effect the weights. On how varying the value tree affected the weights in an evaluation of nuclear waste disposal sites see, for example, Borcherding and von Winterfeldt (1988); see also Pöyhönen and Hämäläinen (1997) and Pöyhönen and Hämäläinen (1998).

Some of the attributes used in the analysis were too vague. For example, the distinction between the *socio-psychological* attribute and the *political cost* attribute was not all that clear. This became even more evident when the impacts were to be evaluated. The costs and health impacts were calculated by the RODOS software, but the qualitative impacts were assessed by the participants. But because it was not really clear what the attributes meant, it was even more difficult to evaluate these impacts.

To incorporate uncertainties in the analysis, utility functions were needed. These were elicited from the decision-makers using lotteries. The utility functions were, however, difficult to construct as it became evident that the decision-makers did not really understand the purpose of, nor the theory behind them. In the short time available it was not possible to go too far into the theoretical details behind the functions. This meant that the participants did not have a very good understanding of what the results meant, and so their commitment to them deteriorated.

The preferences were elicited using three different elicitation methods, but in all cases there was some resistance to make explicit preference statements. Perhaps an interval method, such as the PRIME technique (Salo and Hämäläinen, 1992b), could help to elicit preferences. The decision-makers could then first give a wider range of preferences and gradually refine them when needed. Even though the participants were not really comfortable with the procedures, both overall scores and sensitivity analysis results were shown and discussed. One of the conclusions to be made is that when using RODOS in decision conferences there needs to be sufficient understanding of the decision modelling literature in order to be able to avoid behavioural and procedural biases.

As has been mentioned, in the early phases of an accident a decision has to be taken very quickly. This means that the procedures for making the decision have to be fast and up to the point. Especially when there is so little time available the procedures have to be closely adapted to the intended user. It has been shown that unnatural decision-making procedures are not likely to be followed under time stress (Brown, 1992, Lehner *et al*, 1997). No matter what features are designed into a system, the users will adapt the systems to their needs and resist or even refuse to use the system if it does not meet their expectations and demands (Sambamurthy and Chin, 1994).

In the second phase of the decision conferences uncertainties were included and studied. The general finding was that this is a very difficult subject and that the incorporation of probabilities is problematic. In the conference there was a tendency to ignore the other scenarios and only concentrate on the 95% fractile, which was probably due to the fact that the participants did not have a suitable tool for considering all probabilities at the same time. As mentioned, the participants were not familiar with utility theory and were thus not able fully to use it. These findings are similar to those found at earlier conferences (Ahlbrecht *et al*, 1997).

### 3.2 The RODOS Software

The version of the RODOS software used in the decision conferences in this study, i.e., RODOS-PRTY 3.0, is still a prototype. This means that not all designed functions and features are yet fully integrated in the system. Notwithstanding this limitation, the system was used as much as possible to provide participants with the desired information.

It needs to be emphasised that the models in RODOS are approximations of the real world. A large number of different aspects have been included in the models, but they are still approximations. The decision-makers do not know how the models work, nor do they really need to. But it is important that the assumptions are made explicit and that the models take those factors into consideration which the decision-makers wish to have included, because otherwise they will not feel that the models are adequate, regardless of how sophisticated they are. Because the RODOS system is almost a black box to the decision-makers, it is very important that it is structured in such a way that the decision-makers can trust it. Measurement data is naturally most trustworthy. This emphasises the importance of including as soon as possible a module for presenting observation data.

The most important question is what the decision-makers want from the software, what type of information and in what form? This question is addressed throughout the text. Nevertheless, some points are recited here.

Some specific wishes were made to the RODOS developers during the meetings. At the moment only cancer deaths and not incidents are estimated. For most cancers this was enough, even more than expected (dose was also seen to be appropriate), but not for thyroid cancer in children, where the number of incidents was requested. The estimation of costs should also be expanded to include more items, for example, costs of sheltering and indirect costs caused by the countermeasures. Some participants even suggested that it might be a good idea if RODOS could give rough estimates on the non-quantifiable impacts, such as psychological cost, for instance. If prestructured value trees were used, then it would be appreciated if RODOS could present the data in the same units as would be used in the value trees. These matters will no doubt be addressed in future versions of the software, but it is still important clearly to specify exactly which factors have been included in the calculations and which have not. Then the users will be able correctly to interpret the results.

The presentation of the results is a problematic issue. Although the computational result is a simulation, users are in danger of interpreting the pictures to represent the true case. Thematic maps are used to display most data. But depending on which colours are used and how the cut-off values are defined, the whole impression of the situation can easily change. The operators of the RODOS system have to pay attention to the format of the thematic maps. It may be a good idea to agree on a common format and style, maybe by using a style gallery.

In a conclusion it may be said that the participants seemed to feel that the software produces a lot of valuable information, e.g., on the effectiveness of countermeasures, but that it is of limited help in the actual decision situation with regard to urgent protective actions. At the moment, the participants seemed to be willing to use RODOS as a data base and as a supplementary calculator, i.e., for level 0, 1, and 2 support. Estimates of health effects and costs were appreciated, but using RODOS, in its present form, for the actual decision-making part was not seen to be appropriate. A change in attitude is needed which can be gained with good experience or with examples of level 3 support.

## 4. ACKNOWLEDGEMENT

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