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Confidence
Coping with uncertainty for improved modelling and decision making in nuclear emergencies

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D9.36 Report from stakeholder panels and workshops related to the application of the methods and tools developed in ST 9.1.6

Lead Author: T. Müller

With contributions from: T. Duranova, E. van Asselt, C. J. W. Twenhöfel, S. French, K. G. Andersson, S. Haywood, D. Oughton, J.Q. Smith, C. Turcanu

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Abstract

Task 1 of work package 6 of CONFIDENCE aimed to provide a comprehensive method for better supporting decision making under uncertain conditions, mainly by use of Multi Criteria Decision Analysis (MCDA). While MCDA in general was available for use in the radiological crisis management community, no method of analysing uncertain conditions and supporting robust decision making under these conditions was available. During the CONFIDENCE project, the existing MCDA tool was improved and enhanced to deal with these requirements.

For providing solid and reliable decision support for such a delicate situation as a radiological emergency, the evaluation by the stakeholders and their feedback is important, especially when considering their heterogeneous background due to e.g. living in different countries. Therefore, several stakeholder panels in different countries were organized to include the end users' opinions and to assure the usability of the final tool.

Acknowledgement

This report summarizes the work of many people involved in preparation and organization of the stakeholder panels in Slovakia and the Netherlands, the results of which are available as internal documents. Also documents considering uncertainty in general and selection of MCDA criteria contributed to the evaluation in the panels. The corresponding documents are included in the appendix of this report providing acknowledgement to the people that contributed in one way or another. In particular these documents are:

- "The various meanings of uncertainty"; S. French (University of Warwick), S. Haywood (PHE), D. Oughton (NBMU), J.Q. Smith (Alan Turing Institute and University of Warwick), C. Turcanu (SCK•CEN), Appendix A
- "Stakeholder engagement through scenario-based discussion panels: Report of the [Slovak] National Panel"; T. Duranova, J. Bohunova (VUJE), Appendix C
- "Minutes of the Dutch National Panel"; E. van Asselt (RIKILT), C. Twenhöfel (RIVM) , Appendix E
- "Potentially overruling countermeasure features in decision making based on MCDA", K. G. Andersson (DTU) , Appendix D
- "The CONFIDENCE Dissemination workshop: Scenario based facilitated discussion on decision making under uncertainties", T. Duranova (VUJE), Appendix F

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INTRODUCTION

Goal of WP6.1

Work package 6 task 1 aimed to analyse and support the decision making process in nuclear emergencies, especially with respect to uncertain conditions. Various sources of uncertainty have an influence in this context: the data describing the actual scenario like weather or measurements, the models and software used to evaluate the scenario, the stakeholders with different preferences and environment, just to name a few. A comprehensive overview on the different aspects of uncertainties can be found in the document “The various meanings of uncertainty”, which is included in the appendix.

The tools developed and improved in work package 6 have been evaluated in different national stakeholder panels in the context of workshops not exclusively addressing this topic.

Methods and Tools used in WP6.1

An analysis of the collaboration while making decisions provides a better understanding of the interaction, information flow, and cooperative reasoning of the involved stakeholders, which very often differ in their opinions and preferences. The better understanding of the influencing factors should hopefully raise an awareness of these factors in the long term as well as provide advice and guidelines to deal with them and come to more robust decisions. For analysing the collaboration, agent-based modelling was chosen as this method fits exactly on the requirement, which is to model the interaction of individuals of different behaviour. Furthermore, a questionnaire was created in cooperation with the stakeholders of different countries and of different background to gather the information required for the agent based models. The questionnaire is included in this document as an appendix. The agent-based modelling tool was presented at several workshops but as it is not suited for stakeholder usage without help of an operator, it was not evaluated in the stakeholder panels. Nevertheless the insights gained with the tool should lead to a handbook or guidelines to support stakeholders. As the method was only presented at some workshops, it is not described in further detail.

To support the stakeholders in making their decision in general and especially under uncertain conditions, the method of multi criteria decision analysis (MCDA) was chosen. Firstly it is a well-known method to support decision making especially when multiple stakeholders are involved. Secondly, a basic MCDA tool was readily available as a starting framework, which could be enhanced to address uncertainties in the input. It is worth to mention that the tool and the method of MCDA are very generic and not limited in any way to decision making in radio protection.

Multi Criteria decision Analysis

Multi Criteria Decision Analysis is a decision support method to establish a ranking on a set of alternatives by providing a comparable value $A_1, \cdots, A_n$ for each alternative through integrating a set of predefined criteria $C_1, \cdots, C_m$. Since the criteria values usually are of different units and their values might differ, the values have to be normalized before combining them in a result. Such a normalization can be done by normalization functions $N_1, \cdots, N_m$, such as e.g. min-max normalization, which have to be defined for every single criterion. The criteria are usually of different importance when combined. The importance is encoded in a specific normalized weight $w_1, \cdots, w_m$ for each criterion. Normalized criteria and weights are integrated in a ranking value by an aggregation method. One of the most popular aggregation methods is the computation of the weighted sum, which for each alternative requires the following computation:

$$A_i = \sum_{k=1}^{m} w_k \cdot N_k(C_{k,i}) \quad \forall\, i \in n$$

The results $S_1, \dots, S_n$ are sorted according to their value. The top alternative having the highest value is assumed to be the most preferable one. Figure 1 shows the matrix-like structure of MCDA.

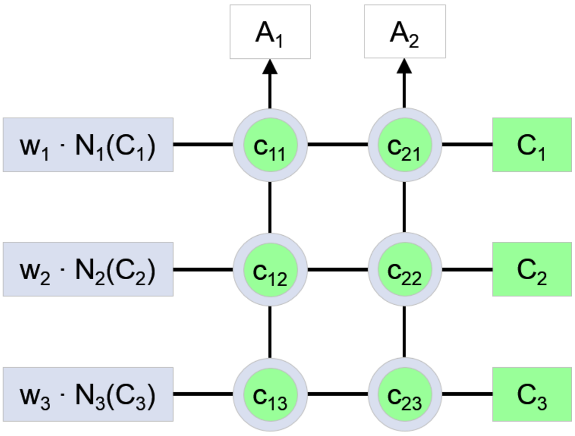

Figure 1. The matrix-like structure of MCDA in an example of 2 alternatives ranked by 3 criteria.

As simple as the method seems, the huge benefit lies in the structured and transparent discussion on 1) which criteria to choose for making the decision and 2) agreeing on the importance, respectively weight of each criterion. The outcome of the MCDA is a ranking of the alternatives, which can subsequently be discussed among stakeholders.

It is obvious, that the presented MCDA method deals only with deterministic criteria and weights and is incapable of handling uncertainties directly, which are naturally described by probabilities. Nevertheless, an ensemble evaluation approach can be used to achieve acceptable processing of uncertainties. First, the MCDA is defined with probabilistic criteria and weights, e.g. by distribution functions or histograms. Then, a deterministic MCDA is generated by randomly sampling from the probabilistic MCDA. The deterministic MCDA can be evaluated in the normal way. The process is repeated and the deterministic based results are aggregated into a statistical outcome.

The improved MCDA tool was presented in the stakeholder panels and used in their discussions. The focus was on defining criteria and weights. Evaluation of uncertainties was presented and debated, however specific uncertainty values of criteria and weights have not been discussed.

Scenario based panel discussion

In all 3 workshops held, the stakeholders were presented with a scenario in the transition phase. Though different origins for the accident were assumed, the materials used and the process applied were very similar in all cases. The material was mainly provided by other work packages e.g. the weather ensemble conditions and source terms. This data was processed by tools like JRodos to provide supporting information like deposition maps. Also ERMIN was used to provide the framing data on urban decontamination such as estimated amount of waste for different strategies.

The stakeholders discussed the tools provided by work package 6 mainly in a large group, except for the final workshop were also subgroups were formed because of the large number of participants. The panels were facilitated to ensure a constructive discussion without biasing specific stakeholders.

THE STAKEHOLDER PANEL IN SLOVAKIA

The full report is available as Appendix C.

Location
VUJE in Modra-Harmonia, Slovakia

Time
10. to 11. December 2018

Participants
19 members from different Slovak organisations

Scenario
The scenario was situated during the transition phase after a fictitious nuclear accident in the Bohunice NPP with external release of radioactivity to environment. The radioactive contamination had spread in the surroundings of the damaged NPP and was transported across borders affecting the neighbouring regions. Early emergency actions had been taken to avoid the exposure to population, including evacuation, access restrictions and food restrictions.

The objective was to decide how to proceed in such a situation and how to recover the contaminated areas. Material like maps and measurements had been prepared, also strategies have been suggested and compiled by the decision support system JRodos. In particular identifying the important criteria to choose among the strategies and determine the according weights had to be done in collaborative work.

Summary
The MCDA decision aiding tool has been presented to the stakeholder panel. They used it during the exercise and suggested how to improve it for “robust” decision making and better usability in a radiological emergency. The tool was helpful in identifying of weights of particular criteria influencing the selection of appropriate strategies. The participating stakeholders effectively used the decision aiding tool MCDA which was helpful in thorough discussions and supportive in making the decisions.

THE STAKEHOLDER PANEL IN THE NETHERLANDS

The minutes of the panel are available as Appendix E.

Location

RIVM, Bilthoven, the Netherlands

Time

26 November 2018

Participants

12 members from different Dutch organisations

Scenario

The aim was to establish the optimal recovery strategy after a nuclear accident for the city of Emmeloord in the Noordoostpolder. Five recovery strategies taken from the HARMONE project were suggested to the stakeholders complemented with a two-month relocation period resulting in eight different strategies. The recovery for the urban area considered e.g. soil, roof, interior removal, and others and ranged from low to high waste options.

Summary

The participants discussed in two separated groups on the criteria they wanted to choose. A comprehensive list of criteria was documented by both groups that could be reused in similar scenarios. In total, 6 criteria were selected to be included in the MCDA: costs, health, public support, feasibility, administrative dilemmas ad quality of life. Some of these criteria could be quantified with data, whereas others (such as public support) were scored by the panel members. While discussing weights of the criteria, the stakeholders felt that some were very easy to determine while others were very difficult and were estimated to be almost equal. The panel members indicated that the decision-maker should provide the weights of the criteria. The obtained values for the criteria and the weights were included in the MCDA and the results were discussed with the panel members. The panel indicated that the tool was very helpful as it allows to distinguish feasible from non-feasible strategies. Furthermore, it provides a transparent tool for decision-making facilitating discussions amongst a diverse range of stakeholders. As a downside of the tool, the panel members indicated that the tool allows only a limited number of strategies and criteria, which in practice might not be sufficient to evaluate recovery strategies. It was suggested to use the tool in exercises and in the preparation stage. Some interesting questions were raised, like in what situation and for whom the tool would be usable. It was suggested to further test the tool in different scenarios and under different conditions to provide according recommendations in an emergency.

THE CONFIDENCE DISSEMINATION WORKSHOP

The full report is available as Appendix F.

Location

Lindner Hotel, Bratislava, Slovakia

Time

4 December 2019

Participants

88 members from different European organisations

Scenario

The scenario used was based on a large fictive nuclear accident at the Borsselle power plant in the Netherlands. Belgium was also affected by the plume. Wide areas had been evacuated. In particular, the task focused on the urban decontamination of the municipality Cromstrijen/Numansdorp. Ensemble calculations of weather and source terms were used to provide frequency maps. ERMIN was used to process the scenario to provide value estimates for potentially used criteria like amount of waste, and residual dose estimations. 5 different countermeasure strategies have been discussed: 1) no actions, only monitoring, 2) low waste strategy, 3) high waste strategy, 4) low waste + relocation and 5) high waste + relocation.

Summary

A selected group of 4 stakeholders who played a role of decision makers have acted as Crisis Centre at a stage and were observed and supported by the remaining participants of the workshop. Discussion among the remaining participants in small groups was encouraged. The crisis manager with the role "mayor" called in additional advisors to support her in the official discussion, thus forming a second group and providing in one voice their decisions. The discussions were facilitated by experienced independent facilitators. The MCDA tool was overhead presented during the ongoing discussion and changes in criteria or weights were interactively observed and evaluated. The different opinions on the weights were investigated in the MCDA tool and then consolidated into one common agreement.

The tool was evaluated to be very helpful for decision makers as it helps a clear structuring of the important facts influencing the choice of an appropriate strategy. Additionally, it triggered interesting discussions on criteria meanings e.g. what "protect the health of the public" actually meant under these conditions, which helped the groups to better understand each other's motivation. It was definitely recognized by participants that the tool has the supportive character and the results could not be taken directly as a tool result as final one. Political decisions as one of the factors influencing the decision was pointed out and experienced in the discussion transparently.

SUMMARY AND CONCLUSION

The stakeholder panel meetings evaluating the MCDA tool can be considered successful. First, the tool in general was well received and the stakeholders' conclusion was, that "the tool can be very helpful in decision making". After each panel meeting, the stakeholders provided sensible advice and suggestions for improvement that in general were followed. Consequently, the tool became more and more tailored to the stakeholders' needs.

Some stakeholders were concerned the MCDA tool on the long term would be used for automatic decision making rendering decision makers obsolete. Yet, during the panels it became clear that the tool would only support decision makers, but can never replace them. It was stressed that the final decision making will always be made by humans despite how sophisticated a tool would be. This was well accepted.

The method itself was understood easily by the stakeholders, which helped to approach the discussion on defining appropriate criteria and weights as well as to interpret the results. Hence they were able to ask the right questions, which improved further understanding and acceptance, e.g. if choosing the highest ranked strategy would be mandatory or should be seen as debatable suggestion, if they could justify choosing a different strategy. Though the MCDA tool was easy to operate, it was suggested to have some trained expert operating it while the stakeholders focussed on the discussion. The panel meetings also showed that a facilitated discussion would be very advisable to moderate the controversy.

Applying the method was technically simple, but choosing the right criteria was not as simple. There were concerns when selecting criteria, if they had to be independent from each other. As obvious example, costs were discussed as they are affecting almost every criterion in one or the other way. In the MCDA community, there is an ongoing debate whether criteria should be dependent or not. Yet, the most important part is that stakeholders are aware of such dependencies. Therefore, the MCDA tool should be operated by qualified stakeholders who are well aware of the meaning of the used criteria. Additionally, it was pointed out that the application of the MCDA could oversimplify the process and could put too much trust into stakeholders for a certain suggested strategy. This relates to some critically important features that should cause stakeholders to carefully analyse and if necessary to override the suggested ranking of strategies. A comprehensive compilation of such features and the according strategies is found as Appendix D.

Furthermore, large sets of strategies or criteria cannot be handled in a satisfying manner. As conclusion, before applying the tool, such large sets have to be downsized. Though this causes additional effort and discussions, it can also be beneficial as it leads to valuable insights how to prioritize the most relevant criteria to be used in the tool.

Most impressive in all panels was the fact that the use of the MCDA tool was not focussed on producing a ranking, as decision makers may choose even lower ranked alternatives if they can justify it, but much more on triggering the discussion to deeper understand the scenario and its defining criteria. Obvious is the discussion of different opinions on weights, which initially varied significantly. Less obvious is the different interpretation of meaning of terms, e.g. what "protection of people" or "acceptance of strategy" actually meant as the stakeholders had totally diverging views on the implication of these terms. As a very beneficial result, the discussion greatly helped to come to a consensus before the actual decision making.

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APPENDICES

APPENDIX A - The Various Meanings of uncertainty

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The Various Meanings of Uncertainty

S. French (University of Warwick, UK)

S. Haywood (PHE, UK), D. Oughton (NBMU, Norway),

J.Q. Smith (Alan Turing Institute and University of Warwick, UK),

C. Turcanu (SCK•CEN, Belgium)

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Abstract

Uncertainty is interpreted differently by different people and disciplines. Moreover, irrespective of interpretations there are many forms of uncertainty, including:

- stochastic uncertainties (i.e. physical randomness)
- actor and process uncertainties (uncertainties about what others may do as decisions are implemented)
- epistemic uncertainties (lack of scientific knowledge)
- judgemental uncertainties (what models to use and how to compute them)
- computational uncertainties (uncertainties about the accuracy of calculations)
- modelling uncertainties (i.e. however good the model is, it will not fit the real world perfectly).

There are further uncertainties that relate to ambiguities (ill-defined meaning) and partially formed value judgements including social and ethical uncertainties (i.e. how expert recommendations are formulated and implemented in society, and what their ethical implications are). Furthermore, some uncertainties may be deep; i.e. within the time and data available to support the emergency management process, there is little chance of getting agreement on their evaluation or quantification. Lastly, there are uncertainties related to the depth of modelling and analysis: has enough been done to support the decision or conclusion?

A key objective of the CONFIDENCE project was to address the decision-making uncertainties in a nuclear accident. This report discusses the various uncertainties that may arise in a nuclear accident from the earliest moments when a potential release becomes apparent, through the release phase and into longer term recovery. In doing so, we note what approaches exist for modelling, analysing and addressing each type of uncertainty, and that in some cases the different modelling methodologies are not always mutually compatible. Throughout we discuss the issues and challenges in communicating the different uncertainties to emergency managers, stakeholders and the public. Thus, this report serves as background to the main deliverables of the CONFIDENCE Project.

Note

The first version of this report was prepared early in the CONFIDENCE project to clarify what we meant by each type of uncertainties. In it we recognised that there would be many things on which we would lack knowledge, many issues on which we would be unclear, and that decision support systems and processes would need to support the managers in dealing with these, perhaps in several different ways. This version has been prepared as the project comes to an end. It incorporates much that we have learnt during the project. Some of our terminology has changed over the course of the project as we discussed issues both within the project, in the wider NERIS (www.eu-neris.net) and CONCERT (www.concert-h2020.eu) communities.

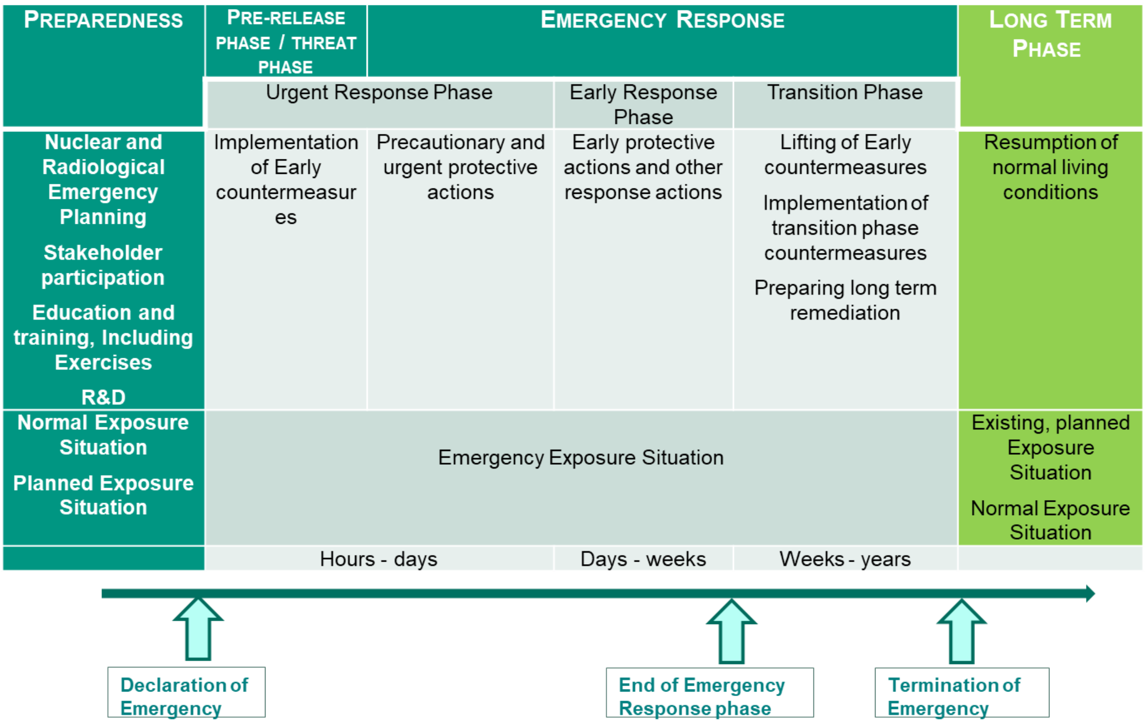
Introduction

Few would disagree that uncertainties pervade emergency management and the case of nuclear accidents is no different. Yet RODOS, ARGOS, other decision support systems and the emergency management processes which they support have, at least until recently, paid lip service to uncertainty in providing information on the current and predicted situation. Indeed, few procedures followed by emergency managers in their discussions really address uncertainty (French et al. 2016, French et al. 2017). One of the key objectives of the CONFIDENCE project has been to consider uncertainty handling more carefully, modifying RODOS and making recommendations on better procedures to take into account the myriad of uncertainties, including social and ethical aspects. Furthermore, such procedures need to be consistent in that good decision making needs uncertainties of the same type to be dealt with in the same ways. Post-accident audit and inquiry would pillorise emergency managers and recovery teams if their actions were driven by incoherence and inconsistency. More importantly, inconsistencies in the management of the Chernobyl Accident led to increased public stress, morbidity and mortality (Karaoglou et al. 1996, Rahu 2003, IAEA 2006), and that the same seems to have arisen in the aftermath of the Fukushima Daiichi Disaster (IAEA 2015, Blandford and Sagan 2016, Hasegawa et al. 2016). In short, failure to address risk and uncertainty in a coherent, transparent and socially relevant way may – and the evidence shows probably will – impact detrimentally on health and social wellbeing.

We shall not describe in detail the full processes of emergency planning, response and recovery in relation to nuclear accidents. Figure 2 summarises the terminology. We refer to those responsible in the different phases as emergency planners, emergency managers and recovery teams respectively.

Uncertainty is a word with a host of meanings. It relates to being unable to answer questions precisely: e.g., in the immediate response to a nuclear accident,

Figure 2: The different phases of emergency planning, response and recovery. (From the NERIS Strategic Research Agenda: see www.eu-neris.net)



- What is the source term, its composition and strength and how will these vary over time?
- How will the public respond in terms of self-evacuation, uptake of stable iodine tablets, and generally following advice and thus conforming to the basis on which protective measures are justified and adopted?

These are just two examples of the many uncertainties that emergency managers and their analysts must consider. Note particularly that neither question relates to a single source of uncertainty, but rather several confounding uncertainties, which need to be tackled consistently before decisions are made. Both examples relate to an inherent lack of knowledge about how things will develop. Both also relate to lack of complete data about the past or the present. In the first case, we may not know precisely the inventory and radionuclide composition of the core before any release, we may not know the energy of the release nor its start time; indeed, we may not know its precise location. In the case of the public, we are unlikely to know who was in the area of the release, whether they followed instructions on sheltering or uptake of stable iodine, the precise protection offered by sheltering in their homes, and so forth. Later, those managing the recovery and planning, e.g., particular agricultural interventions (deep ploughing, crop changes, etc.) will need to consider questions such as:

- If we apply this portfolio of agricultural interventions to these fields, will they be suitable for milk production) from grazing cattle in two years' time (i.e. will radionuclides in milk be at allowable levels?

Again such questions cannot be answered by considering a single source of uncertainty. Many other complex uncertainties relating to our knowledge of what is happening will arise as the response passes through the pre-release, release, post-release and recovery phases.

There are also questions that seem to relate to uncertainty, but which are of a very different type, relating to value judgements: e.g., the emergency managers may be unclear on the trade-off between immediate public health and long-term public health. Moreover, while emergency managers have the responsibility of taking decisions, it may be uncertain whose values should drive their decision-making. The government's, the local population's, wider society's? Further similar questions will arise as the accident progresses into the longer term recovery stages. Such questions relate to the difficulty of making value judgements, particularly if they need to altruistic. Different methodologies and forms of analysis may be – we would argue, *are* –needed to answer them.

Commentators on an earlier version of this report asked whether we should use the word 'uncertainty' in the many senses that we do below. Surely they suggested, as scientists, we should define the term more tightly, perhaps restricting it to contexts in which probability modelling is, conceptually at least, appropriate. Our response is that emergency managers and stakeholders use the term much more widely. This was confirmed in several studies in CONCERT related activities: see, e.g., Table 1. We do not believe it helpful in times of crisis to demand they correct their terminology to a scientifically accepted sense. However, we do believe that it is important that we unpack the meanings of the different types of uncertainty so that there is effective communication between all those involved in managing a nuclear emergency.

With this motivation, the purpose of this report is to summarise issues relating to uncertainty, its modelling, analysis and communication. Note that we have added to the previous version some introductory discussion on the communication of uncertainty, particularly in relation to communicating different types of uncertainty. We have also modified our terminology and organisation of uncertainty types a little as a result of much constructive discussion of the ideas within

Table 1: List of responses from emergency managers and stakeholders when asked about what their uncertainties would be during a nuclear accident (Perko et al. 2019).

- What is the origin of the first information?
- Is the information exchange sufficient?
- Which tools of information exchange are reliable?
- How to deal with time pressure?
- Which factors impact information exchange?
- How is information understood by different stakeholders?
- Is information consistent?
- Are all emergency actors informed timely?
- How to communicate negligible impacts?
- Is Information Communication Technology reliable?
- Which information is public and which information should be restricted to the emergency management?
- How public communication/information needs will be addressed effectively?
- Which areas will be affected?
- How serious is the accident?
- How to decide on protective actions?
- Which protective actions to apply?
- How to implement protective action?
- Will people follow the instructions or recommendations given?
- How to deal with long-term consequences?
- When is the time of the beginning of the release?
- How to deal with technical aspects (e.g. source term) during the early phase of the emergency?
- Is radiological assessment consistent?
- How to interpret dispersion models maps?
- How to coordinate cross-border aspects?
- How coordination and collaboration among emergency response actors will be achieved?
- Is there a gap between legislation (including plans) and reality ?
- Are the preconditions of the functioning systems taken into account?
- Are all emergency response actors familiar with their roles, procedures and plans?
- Are the available resources adequate?
- Are the emergency actors familiar and trained to use equipment?
- Are social and ethical considerations taken into account?
- What comes first: Safety or security?

both the CONFIDENCE project, the TERRITORIES Project (www.territories.eu) and the NERIS Network (www.eu-neris.net).

In the next section, we note the importance of adopting sound ways of communicating uncertainty and recognising that the questions that emergency managers, stakeholders and the public ask may not be immediately answered by some of the technical analyses of uncertainty. We then list several types of uncertainty, not quite in the abstract, but without setting them firmly in the context of nuclear accidents. In doing so, we provide many pointers and guides to the literature. It is important to realise that uncertainty is a complex subject. Research within many disciplines, though particularly in statistical, risk and decision analysis, have established sound, coherent ways of addressing it. We note forms of modelling and analysis that are appropriate to each type of uncertainty and also make a number of remarks on how the different uncertainties might be communicated. Sadly, there also exist naïve approaches that offer 'snake-oil' simplistic solutions, falsely promising to deal with complex uncertainties with little thought or effort. We warn against some of those. The fourth section considers specific issues in relation to emergency management and identifies relevant approaches to their resolution. Finally, we provide a short conclusion and summary table.

Table 2:	**Eight stages towards maturity in risk communication and stakeholder engagement (Fischhoff 1995). The 'we' are the government authorities and the 'they', the public.**
1.	All we have to do is get the numbers right.
2.	All we have to do is tell them the numbers.
3.	All we have to do is explain what we mean by the numbers.
4.	All we have to do is show them that they've accepted similar risks, values, costs in the past.
5.	All we have to do is show them that it's a good deal for them.
6.	All we have to do is treat them nice.
7.	All we have to do is make them partners.
8.	All of the above.

Communication between Advisors and Decision Makers and on to the Public

The Chernobyl Accident, various health scares in the UK and other major events, health and public risk concerns worldwide during the 1980s and early 1990s gave a considerable impetus to developing sound ways of communicating about risk to the general public and more focused groups of stakeholders. It had been known for some time that individual's and the public's perception of risk did not necessarily correspond with what might be called the 'scientific facts', but that knowledge had not really been drawn together into useful guidance on how risks should be communicated in ways to minimise miscommunication and unnecessary stress. In 1995, Fischhoff published a seminal paper that envisaged eight stages in the developing maturity of a government, public body or, in our case, emergency managers and recovery teams in their risk communication with the public and stakeholders: see Table 2. This presaged substantial work across the world to develop practical guidance on how to achieve greater maturity, both in the 'wording' and fine details of communication. This has led to related developments in stakeholder engagement and public participation in societal risk decisions (Bennett and Calman 1999, Beierle and Cayford 2002, McDaniels and Small 2004, Maule 2008, Renn 2008, Bennett et al. 2010, Rossignol et al. 2015). Within the nuclear field, particularly in post-Chernobyl actions, there have been many developments (see, e.g., Heriard Dubreuil et al. 1999, Papamichail and French 2013, Perko et al. 2013). The CONFIDENCE Project is providing many further contributions towards improving nuclear emergency planning, management and recovery processes towards levels 7 and 8 in Fischhoff's vision.

Our focus on communication in this report will not be nearly so wide. That task has fallen to other activities and reports in the CONFIDENCE and TERRITORIES projects. We will confine attention to what precisely the uncertainties are that need to be communicated. After all, if we are not clear on what we are talking about, then we are unlikely to communicate well. Thus what are the uncertainties that need to be explained by the analysts to the emergency managers or wider recovery team; and then how should these be explained onwards to politicians, local communities, other stakeholders and the public.

One point that we would make is that natural language is *not* a good means of communication uncertainty if used without care. People interpret words such as 'probably', 'unlikely' and 'quite possible' very differently. There have been many studies showing this (Teigen and Brun 1995, Rowe 2010, Dieckmann et al. 2015). Moreover, there are variations across cultures which means simple translations of words or phrases may not translate well in what is understood by different levels of uncertainty (Doupnik et al. 2003). The *Intergovernmental Panel on Climate Change* (IPCC) has made considerable efforts over several years to use a formalised system, a *probability lexicon*, to express uncertainties qualitatively to inform a range of governmental decision makers and stakeholders. However, ongoing criticism suggests that they may not have been unambiguously successful (Budescu et al. 2009, Harris and Corner 2011, Cooke 2015). Even if care is taken to define a probability lexicon, i.e. a list of uncertainty terms that are carefully defined in terms of numerical probability ranges[1], unless the lexicon is used regularly in everyday life, it would not be intuitively interpreted correctly in an emergency. To instil the lexicon into regular use would involve a rather draconian programme of educating decision makers, analysts and the public(!) to use language in a very precise way.

A further point is that communicating spatial uncertainty is difficult and relatively poorly researched (French et al. 2018). Spatial uncertainty – or geographical uncertainty, if you prefer – relates to representing the relative likelihood of an effect at different points, e.g. plotting the probability of exceeding an intervention level at different points on a map. Many of the uncertainties that arise in nuclear emergency management have spatial elements. Plotting contours of spatial uncertainties on a map can quite correctly show a rather large area 'at risk', but can also create an impression that the scale of the accident is considerably larger than in fact it is likely to be (French et al. 2016).

In the next section, we discuss various ways of categorising uncertainty, though we use the term 'category' rather loosely. Our categories will not be mutually exclusive. They will overlap a little; some may invite sub-divisions. In any specific case, it may not be absolutely clear which category an uncertainty falls into. However, the process of thinking about how it might be categorised is helpful in that we recognise the range of factors affecting our overall uncertainty and that can be helpful in communication. Moreover, the process inevitably helps us recognise assumptions in out modelling and analysis that need to be communicated to the decision makers and explained to others.

Types of Uncertainty: an Overview

Just under a century ago, Knight (1921) distinguished two types of uncertainty: unquantifiable versus quantifiable. The former he and later workers referred to as *strict uncertainty*, the latter as *risk*. Subsequent discussions developed subcategories of these, and Berkeley and Humphreys (1982) discussed seven types of uncertainty. French (1995) discussed ten types of uncertainty and now admits that he forgot some. Taking a perspective from the growth of knowledge, and, thus as a corollary, the reduction of uncertainty, Snowden (2002) recognised four broad categories (see also French 2013). We could go on. In short, there are many ways of categorising uncertainty and no real agreement on how to do so. So here we will be pragmatic. We make no claim that the list below is exhaustive nor that it separates different types of uncertainty unambiguously. We do believe, though, that it forms the basis for a discussion and that it improves our understanding of the uncertainties that emergency managers and recovery teams face in dealing with a nuclear accident and its aftermath. Moreover, to emphasise one of the points that we shall develop below: categorising an uncertainty is only a preliminary step towards the more important question of how we should support decision makers in recognising and dealing with that uncertainty in their deliberations.

Stochastic or Aleatory Uncertainty

Many uncertainties arise from randomness within many physical behaviours or natural variations in populations and are referred to as *stochastic* or *aleatory* uncertainties. Obvious examples of physical randomness include the toss of a coin, the amount of rain that falls within a particular hour at a

[1] E.g. *Likely* might be defined as describing events that have between 66% and 90% probability of occurrence.

particular point, and radioactive decay. Whether the world is truly random or whether it is so complex that the slightest variation in conditions can dramatically affect the outcome of a deterministic behaviour does not matter to our discussion here. What matters is that we cannot predict an outcome with certainty: we need probability. There is general agreement across the scientific and lay communities that probability models are the appropriate means of describing uncertain behaviours in physical systems. Similarly, probability is the accepted way of modelling natural variation such as the heights of adults in a population or the amount of dairy products in an individual's diet.

School mathematics introduces us to probability in games of chance, and the same theory and principles may be used to analyse and forecast natural randomness and variation. The interpretation of probabilities in terms of whether they represent long run relative frequencies (Von Mises 1957), propensities to adopt different states (Popper 1959) or a subjective degrees of belief in different outcomes (De Finetti 1974, De Finetti 1975) may be moot, but its mathematical use to represent, model and analyse uncertainties that arise from natural randomness and variation is effectively universal.

When we seek to measure any natural quantity, we are face not just possible variation in the quantity itself, but also random errors that arise in the measurement process. Thus measurement errors are modelled and analysed using probability. As a result, probability theory lies at the heart of statistics, the discipline that guides us in drawing inferences from measurements, i.e. data (Barnett 1999, Migon and Gamerman 1999, French and Rios Insua 2000).

Because of our familiarity with probability models and statistical ideas, generally we are well able to model and analyse stochastic uncertainties that arise in nuclear emergency and recovery. We may not be able to do so because of computational limitations and time pressures, but we do understand these uncertainties and usually we can communicate them reasonably well to decision makers and to the public.

Actor Uncertainty

In decision-making, one needs to consider how other actors will behave. For instance, after a nuclear accident many uncertainties relate to the behaviour of the local public. Will they comply with advice on protective actions and if they do, how well will they implement those actions? Will the advice and information offered by the authorities reassure or could it increase stress and hence risk non-radiation health effects? Then there are uncertainties relating to implementation of clean up and recovery actions. Will workers hosing streets forget or miss a side road? Will the public follow advice not to forage for berries, herbs or fungi? There is a need to forecast compliance and the effectiveness of implementation of decisions.

It is possible to model human behaviour using probability models which effectively assume that over a population, variations in how people act can be described stochastically. Simulation models including agent-based modelling, used perhaps to predict behaviour in evacuation, do this. So do many countermeasure models, perhaps forgetting the variation and just using averages. However, humans think, and their behaviour is not random. It is driven by their wants and desires. It may not be rational, but it is directed. There are models of human behaviour that may be more useful than simply using a probability distribution to predict the actions that people take: e.g. prospect theory (Kahneman and Tversky 1979, Mercer 2005, Barberis 2012). There are developments in adversarial risk analysis, which model interactions between individuals, allowing that each may adopt different levels of 'rationality' (Banks et al. 2015). However, such models are a long way off application in the complexity of responses to a nuclear accident. For the foreseeable future, actor uncertainty is likely to be modelled and analysed as if the behaviour is stochastic. Moreover, in many circumstances, there will be insufficient data to build probability models. Instead the judgement and experience of experts will be needed to forecast behaviour and the effectiveness of implementation of protective measures. Ideally structured expert elicitation procedures should be used in working with experts in this way (Dias et al. 2018), combined with a careful sensitivity analysis.

Although actor uncertainties are difficult to model, they are easy to communicate. We all understand that other people's behaviour is not entirely predictable and that others may make mistakes – though we may not understand this about ourselves! So analysts may say to decision-makers words to the effect that part of the overall uncertainty is that we do not know exactly how people will behave. Decision makers and the public will understand this conceptually. The issue is more about how to communicate the scale of the uncertainty.

Epistemic Uncertainties

Some uncertainties relate to our lack of knowledge or incertitude. We may know that something happened, but be unsure when it did. Of course, the time it actually happened is fixed: there is no randomness. The uncertainty has a different character to stochastic uncertainty. In a more scientific context, we may have a number of competing theories to describe some physical behaviour, but we may not know – be *uncertain* about – which, if any, of those theories is true. Epistemology is the study of knowledge and its growth, particularly justified or validated beliefs, so it is natural to refer to such uncertainties as *epistemic* or *epistemological*[2]. It is also natural that statistical theory which articulates the process of scientific inference or induction has considered how epistemic uncertainty should be introduced and dealt with in analyses. Frequentist approaches, which once dominated statistical methods, eschew *full* quantification of epistemic uncertainty leaving the scientist to learn intuitively from the evidence displayed to them in the analyses through *p* values, confidence intervals and significance levels (Barnett 1999). Bayesian approaches, based on quantifying epistemic uncertainty through *subjective* probabilities (see e.g., Savage 1972, French and Rios Insua 2000, Gelman et al. 2013) or *logical* probabilities (see e.g., Jeffreys 1961), now dominate statistical thinking; perhaps more because of the computability of their methodology through MCMC (Markov Chain Monte Carlo) (Gamerman and Lopes 2006) rather than any great philosophical victory. These approaches, based on Bayes Theorem to formalise rational scientific inference, provide a coherent foundation to statistics as well as machine learning, decision modelling and artificial intelligence (French and Rios Insua 2000, Korb and Nicholson 2004, Smith 2010, Rogers and Girolami 2015). The growth and success of Bayesian methods over the last half century provide an empirical confirmation that epistemic uncertainties can be handled practically and effectively through probability.

Although once linked to propositional logic and the encoding of knowledge in language, the probabilities used to model epistemic uncertainty are nowadays usually interpreted as subjective degrees of belief (Barnett 1999, French and Rios Insua 2000). When used in decision analysis for industry and business as well as individuals, the interpretation may be truly subjective reflecting an individual's or small group's personal beliefs. However, some contexts such as science, government, regulation and emergency management require auditable, open analysis representing something close to objectivity. In these, the interpretation is somewhat different. Probability is taken as representing the uncertainty that an idealised rational person beginning with an agreed body of knowledge would hold in the light of the available empirical evidence.

We should also note that sensitivity analysis has a role in exploring and assessing the implications of epistemic uncertainty for the support of specific decisions. Essentially if all plausible explanations and

[2] In the first version of this report we used the term *epistemological* rather than *epistemic*. Both are used in the literature, though epistemic is now the more common and arguably the more correct.

models lead to roughly the same predictions of the possible outcomes of potential actions, any epistemic uncertainty will not be significant *for that decision* (French 2003).

There are two further points that we should make. Firstly, if we do not know the parameters of the probability distribution describing a *stochastic* uncertainty, then that lack of knowledge is an *epistemic* uncertainty. Fortunately, since both stochastic and epistemic uncertainties can be modelled by probability distributions that obey the same mathematical laws, this is not an issue in the quantitative analysis. Whatever their interpretation, probability distributions behave in the same way in modelling and calculation.

Secondly, Knightian ideas which suggest that some uncertainties, particularly epistemic ones, may not be quantifiable are currently under discussion again, though now they tend to be referred to as *deep* (French 2015) or *severe* (Comes et al. 2011) rather than strict uncertainty[3]. Some of this discussion is, to be frank, naïve, returning to long discounted approaches that were debated extensively in the 1950s: see, e.g., Milnor (1954) and French (1986). However, the discussions about deep uncertainty do raise issues that are particularly important for emergency management. There are undoubtedly circumstances in which we know too little to build a probability model of our uncertainty *convincingly in the time available*. There may be little agreement among experts about what is happening nor how to model the behaviour. Several explanations of a phenomenon may be plausible and lead to a wide range of quite distinct predictions. Moreover, relevant data may be sparse. In such cases, we might call our uncertainty *deep*, but that does not mean that it will always be deep nor that *conceptually* it could not be modelled by probability. Rather it suggests that we should gather relevant data, engage in discussion with experts and develop an understanding which we can model and about which we can quantify our uncertainty in probabilistic terms. The problem is that to do this takes time, maybe decades in the case of some of the more fundamental uncertainties in science. In emergency management we have little or no time. So we need a way forward, perhaps scenario-focused approaches (French et al. 2017), which may be thought of as gross, quick and dirty sensitivity explorations. We return to this issue below.

Turning to communication, it is often difficult for non-scientists to understand epistemological uncertainty and its scale. This may be less so for the social, political and economic sciences than the physical and biological ones. But in all cases, there is a tendency to overestimate our knowledge, to live in the model rather than the real world. It is important, therefore, that experts and analysts emphasise to the emergency managers and recovery teams where their knowledge is weak and explain the scale of uncertainty that this introduces.

Judgemental Uncertainties

It is seldom the case that it is obvious which model to use to describe a situation. Maybe in physical dynamics it is obvious that Newtonian mechanics should be used; but that is not so in modelling atmospheric or hydrological transport, food chains or health impacts. In each case there are many candidates of models to use. For instance, there are many atmospheric dispersion models: Gaussian plume, Gaussian puff, particle models, etc. There is little agreement on which is the *right* model to use, though all recognise that the virtues of simpler models are more to do with computational feasibility than accuracy. So in the event of any accident, a judgement has to be made about which model to use, and that leads to *judgemental* uncertainty. This may have been made *a priori* when planning emergency management procedures; or it may be made on the fly at the outset of an accident from several models built into emergency management systems. Either way a judgement is needed.

[3] Note that there are further meanings of *deep* uncertainty in the machine learning and artificial intelligence literatures which are not relevant to our discussions here.

That judgement has implications for the overall uncertainty within the analysis. Furthermore, models and computer codes involve parameters: some relating to the *science* of the model, e.g. transfer coefficients; others relating to the computational algorithm used to calculate with the model, e.g. convergence criteria or grid sizes. Both types of parameter are set judgementally by the users drawing on their expertise. Some parameter choices may be embedded in the code, barely noticed and set to default values, but those default values will again have been set by judgement, perhaps by the code's creators. In very few cases will these parameters be known precisely; to some extent their values will be best guesses. So the user must consider how the specific choice of these parameters may affect the predictions of the code. In some cases this may be done using Monte Carlo methods (Evans and Olson 2002), drawing samples from probability distributions representing the parameters' uncertainty, though this risks an infinite regress relating to uncertainty about hyper-parameters in the distributions used. Alternatively a variety of more deterministic sensitivity analyses may be conducted (Saltelli et al. 2000, Saltelli et al. 2000, French 2003, Saltelli et al. 2004).

Computational Uncertainties

Sometimes we use a single model to describe some behaviour, but more often than not we use a sequence of models (French 2015). We may begin with a cognitive model that embodies complex scientific laws, expressed as precise mathematical formulae, or with a regression model, expressing correlations between inputs and outputs, but again giving us a mathematical formula. It might be an implicit model i.e. the solution of an equation. Those are the models that capture our best understanding of the physical and biological worlds, the uncertainties that arise stochastically or through actor behaviour and our uncertainties that arise from our lack of knowledge. But then we need to implement and calculate using those models. We develop computer codes using approximations, iterations and enormous numbers of arithmetical calculations based on finite mathematics even if we are working with continuous functions. In doing so, we inevitably introduce errors: i.e. *computational* uncertainties. We may find that the computations are intractable in feasible time, so further approximations may be introduced to increase speed and hence computational uncertainty. Statistical emulation takes this one step further by fitting a complex model with a much simpler Gaussian process, a sort of functional regression (Craig et al. 2001, O'Hagan 2006, Conti et al. 2009, Goldstein 2011), again increasing computational uncertainty. Numerical analysis provides bounds on computational errors in specific calculations; emulation algorithms provide some assessment of their own accuracy. Recently Hennig et al. (2015), following earlier work by, e.g., O'Hagan (1992), have promoted probabilistic techniques for representing overall computational uncertainty.

Model Uncertainty

However good the model and computations, the outputs will not fit the real world perfectly. Even if there were no computational approximations and no stochastic elements to real world behaviour, the model would not be perfect. As the truism says: the only true model of reality is reality itself. Over the years attempts have been made to model the gap between a model and reality (Draper 1995, Goldstein and Rougier 2009, O'Hagan 2012). But the task, though informative in understanding the process of modelling, is fruitless, creating an infinite regress of models modelling errors of modelling error models. In many cases, this is a conceptual nicety since the models concerned are clearly more than accurate enough for the task concerned: e.g. calculating a road distance between two points from a map on a GIS. But in other cases, modelling error may be significant and that the model only gives broad indications of the real behaviour: e.g. a model of the spread and migration of an animal population. The papers cited above provide some techniques to allow for modelling error in fitting models to data, broadly inflating variances to smooth the fitting process. However, in using models for prediction, one has to rely on the user's experience to allow for 'how good the model is' (Kuhn 1961).

It is clear that there are considerable overlaps between our definitions of judgemental, computational and modelling uncertainty. We did warn that our categories would not be mutually exclusive. The important point to recognise is that modelling and analysis, the judgements, choices and approximations made in the calculations introduce uncertainties over and above the stochastic, actor and epistemic uncertainties that we are modelling. This needs to be explained to the emergency managers, recovery teams, stakeholders and the public, and it is not easy to do so. Consider how often the media and the public misinterpret as hard, accurate numbers the poor upper bounds on the number of radiation-related cancers that have been calculated using the linear, no threshold model, rough estimates of a source term, average diets from a national survey, etc.

Uncertainties resulting from Ambiguity and Lack of Clarity

Judgemental, computational, model and even stochastic uncertainties can be considered specific cases of epistemic uncertainty, since they relate to a lack of knowledge. Ambiguity and lack of clarity are entirely different. They relate to a lack of clear understanding about what is meant by some wording: e.g. the description of a consequence. Some researchers have suggested modelling such uncertainty with fuzzy concepts (Kacprzyk and Zadrozny 2010), especially in natural language processing. For decision-making, however, fuzzy methods are not an appropriate way forward (French 1984, French 1995). When making decisions, we do not need a model of some ambiguity or lack of clarity, particularly in the description of the strategies and the consequences that may result. Rather we need to think more deeply about what we mean and resolve any lack of clarity by conscious deliberation. A common approach to this is via facilitated workshops in which the facilitator continually challenges participants to explore and define much more clearly what is meant by phrases such as 'health effects' (Eden and Ackermann 1998, O'Brian and Dyson 2007, French et al. 2009).

Resolving ambiguity and lack of clarity in modelling and analysis invariably requires value judgements. Indeed, it requires *value-focused thinking* Keeney (1992) in that we need to think about *why* we need to undertake these. What do we want to learn from the modelling and analysis that we are about to undertake? Only by answering such questions can we answer more model related questions such as:

- how should the consequences be defined so that they represent those aspects of the outcomes of possible strategies that are most important in making a decision?
- in responding to the immediate threat of a nuclear accident, should we be concerned only with immediate risks or do we consider the risks from contamination that may extend decades or centuries into the future?
- do we consider impacts just to health, or should we also consider the environment, the local economy, society and the cost of any action?

There are risks in assuming that the possible consequences are so obvious that they do not need to be clearly agreed and stated. For example, without discussion, it should neither be assumed that direct health-related impact is the only significant endpoint, nor that the outputs from current modelling tools and emergency management systems are the only descriptors of consequences that need be considered in decision-making.

The uncertainties embodied in these questions, i.e. the ambiguities and lack of clarity about what matters, are often called *endpoint uncertainties*. These uncertainties are not just important in themselves; resolving them has implications for what other uncertainties need be modelled and analysed and to what depth. Once we know what we are trying to assess and what is really important to us, we can ignore uncertainties that do not feed through to these endpoints.

It is self-evident that resolving ambiguities and lack of clarity is essential if analysts are to communicate with emergency managers, recovery teams, stakeholders and the general public. It is imperative that the reasons behind decisions that have been taken, the countermeasure and remediation strategies to be implemented, and the expected consequences are all communicated well, embedded, of course, in an understanding of the other uncertainties discussed in the previous sections.

Value, Social and Ethical Uncertainties

Some uncertainties relate to questions that much more clearly need require value judgements in their resolution: e.g. how much to trade-off a reduction in radiation exposure for an increase in cost, perhaps taking account of marginal value in the reduction given the current predicted exposure. Such value uncertainties are due to a lack of clarity on the part of the emergency managers on how to articulate general values in the ongoing emergency. They are, however, important enough to consider separately from ambiguity and lack of clarity. Again, modelling such uncertainties is unhelpful; they need to be resolved by thoughtful deliberation, perhaps supported by sensitivity analysis since precision is irrelevant when there is no effect on the ultimate choice.

Value uncertainties introduce social responsibilities and ethical concerns, particularly when acting on behalf of stakeholders. How recommendations are formulated, the legality and validity of their implementation introduce further uncertainty. What is the *right* thing to do on the public and stakeholders' behalf? Again debate and deliberation are the only useful way forward. Many uncertainties relate to value judgements. The emergency managers and those in charge of recovery need to consider how to balance different types of cost relating to strategies and their impacts: health, social, environmental, economic, etc. For instance, managers may be charged with *minimising health effects*, but may not know precisely what is meant by this. What is a health effect? The imperative to *minimise* implies that they must be quantified in some way. But in what way? By number, scale, some combination? Does it matter who suffers the health effect? Should they care more about health effects in children than adults? If the risk is long term, is the focus on immediate or long term health effects in present populations or the health of future generations? Is a physical health detriment to a few more important than a mental health detriment to many? There are a host of uncertainties which need to be unpacked and defined before the imperative to 'minimise health effects' can be operationalised and followed. These uncertainties relating to values and ethics clearly have a different character compared to stochastic or epistemic uncertainties.

Moreover, in resolving such uncertainties, we should recognise that decision makers often aim at representing a wider group of stakeholders, maybe an organisation, a local community or the wider public. This brings to the fore the question of whose values and ethics should be drawn into the decision making. The decision makers need to understand and articulate the values and ethics of the people whom they represent. This can bring into the mix some epistemic uncertainty in which the decision makers seek to learn what their constituents want. Methods of opinion polling may be used which can result in formal probabilistic representations of public values in some sense. But in complex cases, stakeholder workshops and other interactive forms of engagement are perhaps better for providing the decision makers with a qualitative understanding of the values and ethics that should flow through their decisions.

Experience, notably from the Chernobyl and Fukushima accidents but also from non-nuclear accidents, shows that stakeholders' values, ethical considerations, requirements for public communication and the contrasting needs and concerns of people in different environments are key factors influencing the effectiveness of risk assessment and management. In particular, inherent social uncertainties, different perceptions of risk, and societal (dis)trust issues pose important challenges to radiological risk governance. Social and ethical uncertainties are often used to describe the way recommendations and information are taken up by lay people and other publics: whether the advice given by modellers and/or authorities is acted upon. Models are always based on assumptions about the social context where decisions take place, e.g. that people will accept to live in contaminated territories. Therefore, the efficiency of protection strategies depends significantly on the way the social context is understood and accounted for in decision-making. Social and ethical uncertainties can also be attached to the decisions, choices and assumptions made by modellers, scientists and other experts during their 'scientific' assessment: i.e. how they resolve judgemental uncertainties in selecting parameters, data, criteria, target populations or reference organisms, levels of significance for statistical testing, etc.

Social uncertainties in how expert recommendations are implemented in society may refer to public acceptance and compliance with protective actions advice; social and economic consequences of the recommendation and actions, and uncertainties in those consequences; and the level of stakeholder and public engagement used or planned. *Ethical uncertainties* include:

- defining the level at which a risk becomes acceptable, e.g. 10^{-7} for the annual risk to an individual;
- whether members of a population feel that they have given consent to being exposed to a particular level of risk;
- being sensitive to inequalities in the distribution of risk;
- the manner in which autonomy, governance, responsibility, transparency might impact on public acceptance of risk.

Social and ethical uncertainties can also be recognized in expert recommendations. For instance, has there been any discussion on possible societal or economic consequences or of the perspective taken in the modelling, e.g. worst case vs best possible estimate? And are these acknowledged in the expert/authority recommendations or decisions?

Discussing and communicating how value, social and ethical uncertainties have been resolved is an essential prerequisite if public stress during the accident and its aftermath is to be managed effectively. We noted at the outset that the health consequences of stress arising from Chernobyl and Fukushima are of a similar order to those arising from radiation. Public uncertainty about what is happening, what is being done and *why* it is being done is a fundamental cause of such stress.

Uncertainty about the Depth of Modelling

When decisions are taken, a further uncertainty arises: are the analyses sufficient to justify the actions being taken? Is it *requisite,* i.e. 'good enough'? Such uncertainty again can only be resolved by judgement and deliberation (Phillips 1984, French et al. 2009); although in the emergency itself, the need to make timely decisions may supersede this. A balance always has to be made between whether one is comfortable that everything relevant has been considered adequately and whether the need for a decision is so urgent that there is not time to analyse further.

A related issue here is how *confident* the decision makers feel when taking the decision. The analyses and results presented to emergency managers and recovery teams are based on long complex model chains. Along such model chains many data sets are used, many approximations made, many parameters set and many, many calculations made. The models included in the chain are chosen on the basis of judgement and pragmatism, with the latter dominating in the urgency of the threat and release phases. Thus, considerable judgemental, computational and model uncertainties may have accumulated in developing the analysis and results. Such uncertainties, as we have indicated, are extremely difficult to quantify and will not be fully represented in any uncertainty bounds and plots produced. Yet they need to be communicated to the decision makers so that they have as full as possible understanding of the total uncertainty that they face. Within CONFIDENCE, a traffic light system has been developed which reflects the quality of different components and inputs to the model chain, within warning lights indicating that some elements are questionable, although they are the best achievable within the resources and time available.

Broader Groupings

We emphasise again that the list of uncertainties above is only one possible categorisation and that we make no claim that it is comprehensive nor that the categories are non-overlapping. We have, however, found it useful in discussing how to handle uncertainties in nuclear emergency management. In Table 3, we organise these types of uncertainty into three groups. The first group relates to our knowledge of the external world; it might be called *scientific uncertainty*. The second relate to uncertainties and errors that are introduced by the models and techniques that are used to analyse the risks and possible interventions in an emergency. The third relates to uncertainties that the emergency managers, experts and stakeholders hold about themselves, their values and responsibilities. In our experience, in the past most attention and discussion has focused on the first and some of the third group of uncertainties, but much less attention has been given to the second. Moreover, the effects of all these uncertainties have been poorly communicated to the decision-making process.

Cynefin, Epistemology and Uncertainty

We have described several different types of uncertainty and noted that they may need to be addressed in different ways. We should also note that the surrounding context and our knowledge of other aspects also shape how we should deliberate on, model or analyse uncertainty. Snowden (2002) introduced the Cynefin framework to do this. French (2013) discusses Cynefin in relation to decision support, and French and Niculae (2005) used it to explore aspects of emergency management (see also Niculae 2005).

Snowden's Cynefin model roughly categorises decision contexts under four headings: see **Fehler! Verweisquelle konnte nicht gefunden werden.** In the *Known Space* – also called the *Simple Space* or, more informatively, the *Realm of Scientific Knowledge* – the relationships between cause and effect are well understood. All systems and behaviours can be fully modelled. In the *Knowable Space* – also known as the *Complicated Space* or, again more informatively, the *Realm of Scientific Inquiry* – cause

Table 3: Broad Categories of Uncertainty Types
Stochastic or Aleatory Uncertainty Actor Uncertainty Epistemic Uncertainty Knowledge of the External World
Judgemental Uncertainty Computational Uncertainty Model Uncertainty Modelling and Analysis Errors
Ambiguity and Lack of Clarity Value, Social and Ethical Uncertainty Depth of Modelling Uncertainty Internal Uncertainties about Ourselves

and effect relationships are generally understood, but there is a need to gather and analyse further data to set parameters in models before any predictions can be made. Situations which may be classified as lying in the Known and Knowable Space are familiar to us. We have experienced them many times. We are much less familiar with situations in the *Complex Space* – also called the *Realm of Social Systems*. Knowledge here is at most qualitative; too many potential interactions exist to disentangle particular causes and effects. There are no precise quantitative models to predict system behaviours as there are in the Known and Knowable spaces. This is often the case in many social systems, though such complexity can arise in environmental, biological and other contexts. Finally, in the *Chaotic Space* there are no obvious candidates for cause and effect. We simply do not know what is happening and have yet to make sense of things. Modelling and quantitative analysis are impossible because we have no concepts of how to separate entities and predict their interactions.

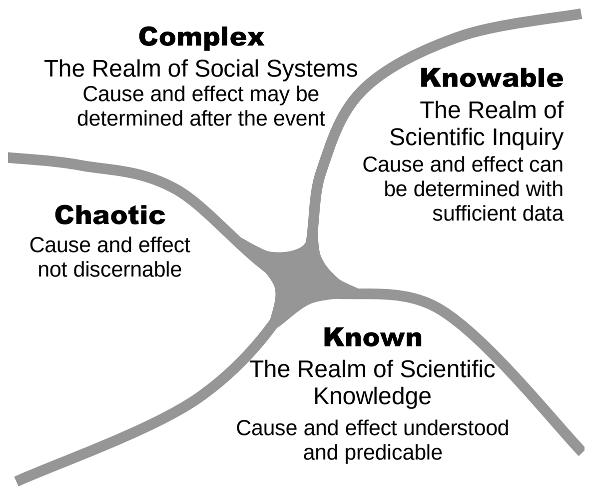


Figure 3: Cynefin

Deep uncertainties occur in the Chaotic and Complex Spaces. The lack of understanding of cause and effect mean that it is impossible to model fully and the epistemic uncertainties may be too great to model probabilistically. Since people tend to act unpredictably in ill-understood circumstance, actor uncertainties can also be deep. Often one can only examine a range of scenarios that span in some sense the range of possibilities. Within the Knowable and Known Spaces, because cause and effect are well understood, one can model effectively, with stochastic and epistemic uncertainties treated probabilistically. Human behaviour is also better understood from many past experiences, so actor uncertainty may be modelled or assessed judgementally. It is also possible to use sensitivity analysis to assess the implications of judgemental, computational and, to some extent, modelling uncertainties.

Moving from the Chaotic Space through the Complex and Knowable Spaces to the Knowable Space, our knowledge and understanding move from very deep uncertainty to certainty. Epistemology from sense-making through inference to full knowledge can be described very simply against the backdrop of Cynefin (French 2013). We would also note that our knowledge of our values change as we move through the spaces. In the Known and Knowable Spaces, familiarity with many similar situations means that we will have thought through our values previously. We know what we want to achieve simply because we 'have been here before'. Such is not the case in the complex or chaotic spaces. Novel issues and lack of full understanding require us to reflect upon what we want to achieve (Slovic 1995). In much of the CONFIDENCE project, we worked with stakeholders to help them deliberate on what their values were in a variety of scenarios, contextualising their fundamental values to those circumstances.

Uncertainties in Nuclear Emergency Management

The strapline of the CONFIDENCE Project has been: *coping with uncertainty for improved modelling and decision making in nuclear emergencies.* Its work-programme expanded on this, seeking "to understand, reduce and cope with the uncertainty of meteorological and radiological data and their further propagation in decision support systems, including atmospheric dispersion, dose estimation, food-chain modelling and countermeasure simulation models. Consideration of social, ethical and communication aspects related to uncertainties is a key aspect of the project activities." Thus it is clear that understanding, modelling, management and communication of uncertainty is central to the objectives of CONFIDENCE. In this section, we discuss how the different types of uncertainty discussed above will enter into this. We exemplify the approach proposed by focusing on two specific areas:

- the threat and early release phase of an accident, including source term, atmospheric dispersion and deposition, and health impact modelling;
- accounting for stakeholders' preferences in planning for and recovery after a nuclear accident.

Our approach is simplified to focus on key principles of dealing with uncertainty. Thus we do not explicitly address hydrological dispersal, agricultural production and food-chain modelling, as well as economic and environmental impacts. Though these processes also are subject to many uncertainties, they do not introduce further conceptual issues in uncertainty modelling. Moreover, we do not discuss in any detail the uncertainties arising in the transition phase. During this phase there are still a lot of uncertainties relating to external situation: depositions will still be being mapped. So many of the issues that arise in the threat and early release phase will continue. Equally there will be a little more time to reflect and consider value and ethical uncertainties in greater detail so that stakeholder engagement may begin. Thus the methodologies for analysing and communicating uncertainties in the transition phase will have aspects of the both those in the threat and release phases and those in the recovery phase.

Uncertainties in the threat and release phases

Fehler! Verweisquelle konnte nicht gefunden werden. presents, in a highly simplified format, the major models that contribute to estimating health impacts during the threat and early phases of a nuclear accident. Its arrows should be read as showing information flows and not temporal relationships. Many models are iterative, as is the entire modelling network. Thus to estimate atmospheric dispersion and deposition, estimates of the source term and local weather forecasts will be required. In turn, if we assume the imposition of swift agricultural controls, health impacts will result primarily from environmental contamination given by the atmospheric dispersion and deposition outputs. All these calculations will draw upon topographical, population and other spatially referenced data collected by a variety of measurement techniques and then stored and perhaps interpolated ('kriged') in a Geographic Information System[4] (GIS) and on assumptions about public behaviour and adoption of advice on countermeasures. Related discussions of the modelling and inherent uncertainty producing radiological emergency response assessments may be found in Haywood (2010) and Haywood et al. (2010).

[4] A Geographic Information System (GIS) is defined by some as little more than a spatially referenced data base; others emphasise the system aspect and take GIS to include all the statistical, analytic and visualisation algorithms used to interpolate and present data in querying and using a GIS. We adopt the latter.

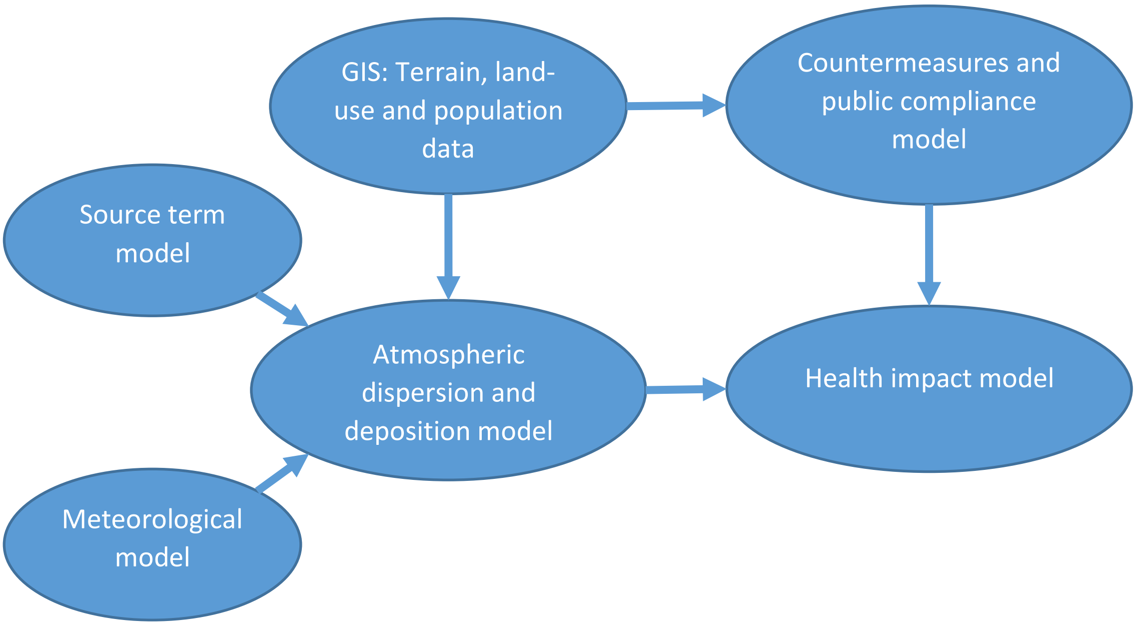


Figure 4: A simplified presentation of the different models that contribute to predicting the health impacts during the threat and release phases of a nuclear accident.

When an accident threatens and during any release, the *source term* is hugely uncertain in many respects: its composition, its profile, its duration, its energy (heat), etc. Some attempts have been made to quantify these uncertainties into broad brush categories using belief nets (Grindon and Kinniburgh 2004), but broadly the approach has been to produce a single prediction based on engineering and nuclear thermodynamic models or simply rely on expertise. It is worth noting that if expertise is to be used, there seem to be no plans to use structured elicitation and avoid biases that may be present when experts are asked for assessments without any formal protocol (O'Hagan et al. 2006, Dias et al. 2018). Source term uncertainties are certainly epistemic and contain some stochastic elements too. The models used will introduce computational and judgemental uncertainties too as some parameters will be set by expertise. However, *conceptually* the overall uncertainty from these aspects can be modelled by probability distributions. Unfortunately, the uncertainties are also likely to be deep: i.e. it is unlikely that the probability models can be produced quickly and convincingly enough within the time needed by emergency managers. We return to this point below.

Weather forecasting is regularly offered as an example uncertainty that we all experience, and the meteorological models here will be no exception. Even though meteorological offices use some of the highest power computing available, their predictions of wind and precipitation will be subject to stochastic, epistemic, judgemental and computational uncertainties. All can be modelled probabilistically and, indeed, meteorology is one of the sciences to adopt probability modelling as fully as is currently possible. The majority of these uncertainties will not be deep, though if there is a possibility of a front passing through the region, its timing may be highly uncertain. The timing and location of showers may be even more uncertain.

There are many atmospheric dispersion and deposition models, each with its own characteristics and set of approximations. Choosing a puff or particle model, frequency of puffs or number of particles, grid size, etc. all introduce judgemental uncertainties. Moreover, these models take outputs from source term[5] and weather models, and from terrain data from the GIS, adding to the uncertainty. The algorithms used to run the models introduce computational uncertainties, and there are two further issues that relate to uncertainty. First, some analyses use ensemble[6] techniques, running the models with a sample of different initial conditions, particle releases and other inputs. There is a common assumption that the set of ensembles produced provide a representation of the uncertainty in the dispersion and deposition predictions. Ensembles certainly provide understanding of the possible extent and scale of the risks. They only provide *probabilistic* assessments of uncertainties in very special circumstances: namely, when the sample of initial conditions, particle releases, etc. reflect the actual uncertainties on the inputs to the model. In Bayesian terms, the ensembles must be chosen to reflect prior knowledge of the relative likelihood of the different ensemble members. Usually ensemble members are generated so that each possible set of values is equally likely. Also, there is no attempt to introduce the judgemental uncertainties from model choice, parameter setting, etc[7]. So the output from ensemble modelling does not reflect the full range of uncertainties present. Ensembles give rise to a type of plot that can be very informative in displaying some aspects of uncertainty *as long as the strengths and limitations of the plots are understood*. These plots show the fraction of ensembles that give the value of some quantity as being above a given value. Suppose that there are 100 ensembles. Each is used to calculate, say, the predicted external dose at a given geographical point (or within a given grid cell). If 62 ensembles predict a two-day dose above a particular value a value of 62% would be plotted. It is easy to misinterpret this as saying there is a 62% probability of exceeding that dose at that point. That misinterpretation is made all the easier because the atmospheric dispersion community have tended to refer to such plots as *probability plots*. Thankfully over the course of CONDFIDENCE, many have begun to refer to these plots as *frequency plots*, though *degree of agreement* plots would be a better term. Such plots indicate areas at risk and the agreement between ensembles and thus the sensitivity of the models to the sort of variation in inputs represented by the range of ensembles. However, unless the ensembles have been chosen to reflect prior knowledge of the likely values of these inputs, the plots do *not* show probabilities.

The second issue concerns the judgemental uncertainty that arises on seemingly the same parameters in different models. For instance, the release height of the source term is an input to many of these models. It gives the *notional* height at which the plume stops rising and begins to spread out. Given possible wind shear, this parameter has a significant effect on determining the direction in which the plume moves off. Analysis against data sets from experimental releases has shown that the numerical value of the release height that gives the best fit for one dispersion model may be quite different to that gives the best fit for another model. In other words, the judgemental uncertainty on a parameter of the source term depends on the dispersion model being used. In general, this issue is true whenever the output of one model is taken as the input for another, but it is particularly apparent in this case.

Emergency decision support systems such as ARGOS and RODOS rely on spatially referenced data from a GIS: residents, industries and businesses including number of employees, dwellings including form of construction, terrain and topography, land use including agricultural production, schools, hospitals, and so on. This will introduce further uncertainties. Firstly, the data itself will be subject to error: even if accurate when input, people move, land use changes, etc. Secondly, the granularity of the data in a

[5] Price et al (2017) have recently surveyed the sensitivity of atmospheric dispersion deposition models to parameter settings in six source term models.

[6] Meteorologists use the term *ensemble* in similar but subtly different ways to statisticians. Here we mean multiple runs of the same model code with different plausible initial conditions and parameters.

[7] Indeed, . Finally, the interdependence of the model runs in the ensemble needs to be considered. Since they use the same model code they are not statistically independent and thus the output of the ensemble runs will not represent the full uncertainty in the dispersion and deposition predictions.

GIS can have quite a gross character. For instance, land use may be recorded as constant over a 100m grid square, so the data extracted from a GIS may be produced by kriging to produce approximate point values at grid points. The temporal variability of such datasets is a major source of uncertainty; for example, whether the dataset represents a daytime or night-time population, and the impact of seasonality (e.g. tourism) and daytime variations (e.g. population movements due to school and work). Not least is the effect of the emergency itself on the accuracy of the data used in the assessment, e.g. unplanned and spontaneous evacuation movements.

The final two models in **Fehler! Verweisquelle konnte nicht gefunden werden.** are of a different character to those that provide predictions of atmospheric dispersion and deposition. There is no detailed modelling: human behaviour is not that well understood. Rather several gross behavioural assumptions are made to get what are effectively ballpark figures. Simple multipliers are introduced to reduce the effectiveness of a countermeasure: e.g. given advice from the emergency managers to take stable iodine, only ξ% will successfully do so or η% will self-evacuate despite advice to shelter. This means that these models introduce very significant judgemental uncertainty, and also judgements that will be more applicable to some emergencies than to others, or to some areas than others. Moreover, in using the linear no-threshold hypothesis to estimate cancer risks further gross assumptions are made about the risks to people in the contaminated environment (Argyris and French 2017).

We have omitted to discuss modelling error in our discussion here. There are two reasons for this. Firstly, while we could consider modelling errors at each of the nodes in **Fehler! Verweisquelle konnte nicht gefunden werden.**, it perhaps makes more sense to consider the overall modelling error taken together in so far as it predicts health impacts with and without countermeasures. The intermediate errors may not be as relevant in supporting the emergency managers. Secondly, our remarks in the previous paragraph about the gross behavioural assumptions regarding compliance and the effectiveness of countermeasures raise the question: how accurate do those elements contributing to the predictions of atmospheric dispersion and deposition need to be? We return to this point below.

It is clear from the above that a wide range of stochastic, epistemic, computational, judgemental and modelling uncertainties are involved in producing predictions of health impacts to provide the emergency managers with information and guidance on their decisions. So how are these currently presented to emergency management teams? Hardly at all! Point estimates are provided and uncertainty is assumed to be handled by discussion between the emergency managers and their support teams (French et al. 2016, French et al. 2017). Those discussions usually relate to stochastic and epistemic uncertainties with judgemental, computational and modelling uncertainty seldom mentioned. It is well known that scientists typically underestimate errors in their model predictions, possibly because the models give plausibility to their results and plausibility is at the heart of a psychological bias decreasing uncertainty (Kahneman 2011, Selin 2014). So it is likely that these discussions do not provide emergency managers with a full appreciation of the overall uncertainty in the predictions being offered to them.

There have long been intentions that decision support systems such as RODOS should provide more formal treatments and assessments of uncertainty for the emergency managers (French 1997, Caminada et al. 2000); and there have been efforts to use Kalman filtering in atmospheric dispersion and deposition models not only to provide uncertainty assessments but also to perform data assimilation (Smith and French 1993, Politis and Robertson 2004). However, these have not been sufficiently developed to be implemented and, moreover, are very limited in the uncertainties included in the modelling. No real modelling of the source term uncertainties is included, nor of terrain uncertainties, and there is no subsequent modelling of the uncertainties inherent in forecasting health effects.

One approach might be to provide emergency managers with several scenarios. Scenario analysis is used throughout business and government to develop strategic thinking (Schoemaker 1995, van der Heijden 1996) and to challenge too great a focus on one specific prediction. The most basic forms of scenario analysis develop a series of maybe 4 or 5 scenarios that are 'interesting' in some sense and may be used as backdrops for discussion about the merits and risks of different strategies. How 'interesting' is defined is moot, with many possibilities. In the case of the threat and early phase of a nuclear accident, we might consider:

- reasonable best and worst cases of some form – useful for bounding possibilities;
- a likely case – useful for maintaining a balanced perspective;
- an assumption that a particular event happens or does not – useful if a key event, such as a second release or the arrival of a weather front, is unpredictable and shrouded in deep uncertainty.

Note that several reasonable best, worst or likely cases might be explored and considered, since no single case will illustrate all potential impacts. Note also that to select a small set of scenarios for further analysis and discussion will inevitably mean that several more, perhaps many more will need be generated and examined quickly. However, only a handful of scenarios would be developed fully and shown to the emergency managers. In crisis management, there is no time to do more. There is also the issue of cognitive capacity in that decision-makers often cannot absorb and balance out the implications of many scenarios (Miller 1956). French et al. (2016) survey the relevant literature on developing an appropriate set of scenarios for the emergency managers to consider.

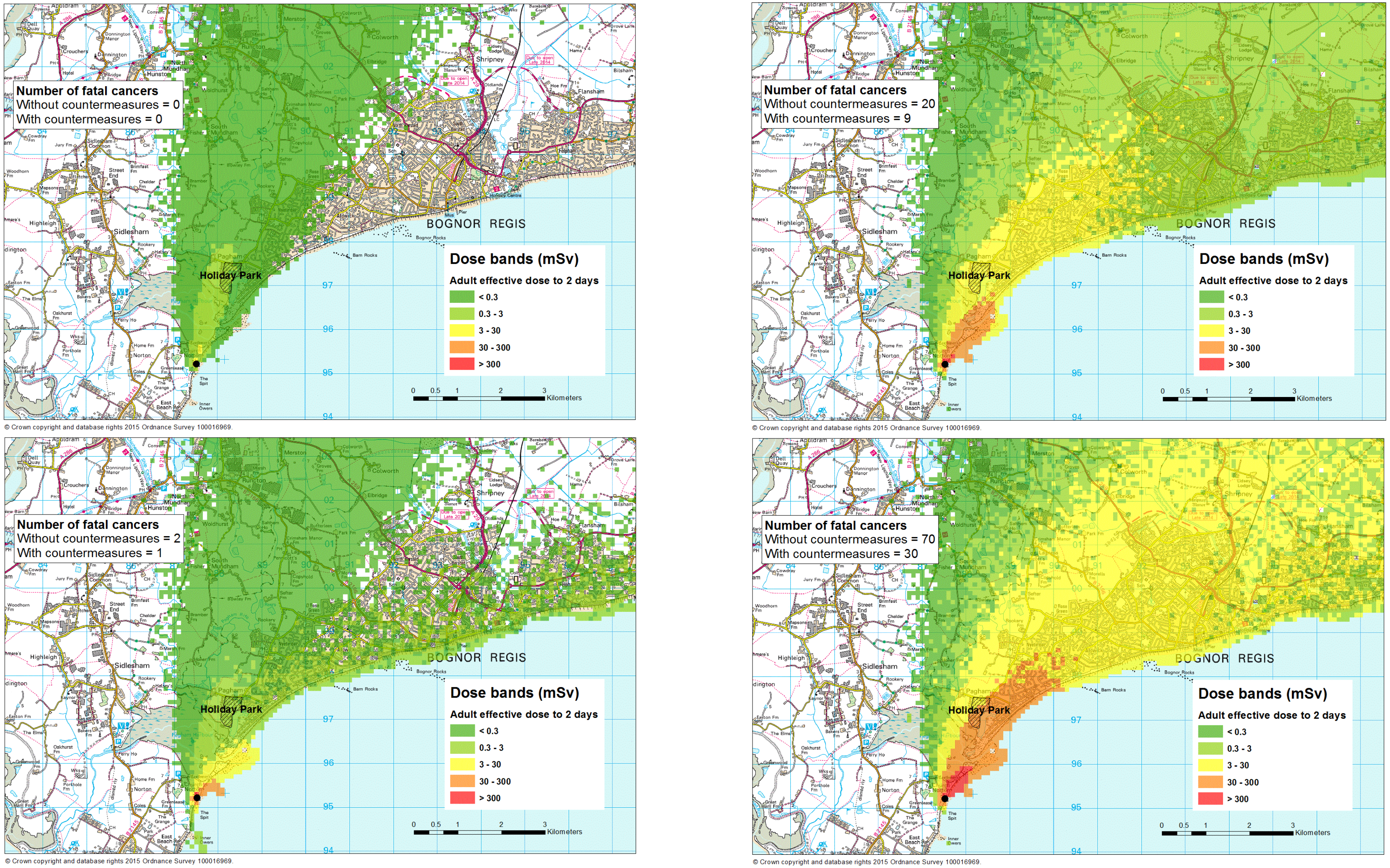


Figure 5: Four scenarios used in a UK workshop to explore alternatives to a single 'reasonable worst case' (RWC).

The presentation of each scenario would include maps or sequences of maps showing the evolution of events under the assumptions implicit in its definition: for an example see **Fehler! Verweisquelle konnte nicht gefunden werden.**. The design of RODOS, ARGOS and other DSS also allow more dynamic presentation of scenarios which would present the emergency managers with several evolutions of the plumes and corresponding regions in which protective measures might or would be needed under national and international guidance. Some initial work has been undertaken to explore these ideas (French and Bayley 2003, Raskob et al. 2009, Haywood 2010, Comes et al. 2013, Havskov Sørensen et al. 2014, Comes et al. 2015, French et al. 2016). It is important to realise that the scenarios are neither mutually exclusive nor span/partition the future, so assigning probabilities to them is meaningless. The key idea in presenting several scenarios is to stretch the crisis managers' thinking and make them consider a wide range of possibilities. It is important, of course, to guard against framing and plausibility biases. This might be done by a continual process of challenge to justify their thinking implicitly (French et al. 2009).

Uncertainty and Stakeholder Engagement

During the urgency of the threat and release phases, it would not be possible to consult stakeholders and the local public in any meaningful fashion, therefore assessments of public behaviour should be made in the preparedness phase, based on experience from past accidents, incidents and exercises, and modelling of expected behaviour. Moreover, the public should be provided with the relevant information (information needed for their own decision-making) and guidance as soon as possible; and note that this guidance should often include assessments of uncertainty. In some countries stakeholders and the local public are regularly consulted during the planning for potential nuclear accidents and the intention is that in the event of a future accident, clean-up and recovery strategies would be discussed with them in depth. In doing this, there will be a need to explore many uncertainties with them. Work Packages 4 – 6 of the CONFIDENCE project are specifically focused on these issues. Within these work packages we need to consider three broad aspects of uncertainty.

i. What is lay persons' and emergency actors' understanding and processing of uncertain information and their subsequent behaviour in nuclear emergency situations;
ii. What are the main sources of social and ethical uncertainties in emergency situations and the transition phase and how to reduce these through better communication, according to the information needs for each particular stakeholder group;
iii. how to learn *from* the stakeholders and the public their preferences on clean-up and recovery strategies and integrate them into decision-making, recognising that they may be unclear on their valuation of these.

In relation to point i we observe that while perception of risks from nuclear accidents and radiological contaminations of the environment have been extensively investigated in the literature, very few empirical studies have focused on lay public behaviour in nuclear emergency situations. However, a substantial body of research, mostly grounded on social psychology, exists regarding lay public preparedness for natural hazards such as flood, earthquakes or hurricanes. Case studies of past accidents and incidents, mental models approaches, naturalistic observation can provide additional insights.

On point **Fehler! Verweisquelle konnte nicht gefunden werden.** there has been a substantial volume of research and guidance published since the earliest post-Chernobyl projects (Drottz-Sjöberg and Sjoberg 1990, Havenaar et al. 2003) and more widely in other domains (see, e.g., Fischhoff 1995, Renn 1998, OECD 2002, US DHHS 2002, Bennett et al. 2010). Reviews of risk perception and risk communications literature can be found in (Renn 2008). More research is needed on communication of uncertainties. In particular, French et al. (2016) note the dearth of research and guidance on also communicating spatial risk and presenting uncertainty on maps.

It is point iii on which we concentrate here: how do we learn from stakeholders the values that they should like to drive emergency and recovery decision making. Firstly, we should note that stakeholders may be unclear on their values in relation to emergency response to a nuclear accident. Thankfully, the vast majority of people have not experienced a serious threat of release of radiation from a nearby nuclear plant. For them, it would be an entirely novel situation and thus it would be categorised as lying in Cynefin's Complex Space. As we noted, people seldom have clearly formed values in relation to such situations: they will still be learning and thinking about what the experience means for them. In the event that an accident has occurred and they are being consulted on recovery, this may be particularly true: a catastrophe and its aftermath can change people's fundamental values (French et al. 1997). Thus we cannot simply ask stakeholders for their values. We need to help them discuss, think about and, indeed, form their values and preferences. Many of the approaches to stakeholder engagement and public participation in decision making use multi-criteria decision analysis (MCDA) to articulate such exploratory discussions (Rios Insua and French 2010, Gregory et al. 2013, Papamichail and French 2013). CONFIDENCE work packages 4 – 6 have investigated such methods, taking stock of work from earlier projects such as EVATECH and EURONOS.

Like 'uncertainty', MCDA is a somewhat ill-defined term covering many methods and approaches, sadly often incompatible approaches (Bouyssou et al. 2000, Belton and Stewart 2002, Bouyssou et al. 2006). There are several schools of MCDA, each based on its own set of assumptions, sometimes explicitly stated, sometimes left implicit. Multi-attribute value theory (MAVT) provides arguably the most justified and frequently used approach being based upon explicit, well discussed and explored sets of assumptions (Krantz et al. 1971, Keeney and Raiffa 1976, Keeney 1992, Wakker 2013). There are linear and non-linear versions appropriate to different sets of attribute preferential independence conditions. MAVT approaches may be developed naturally into expected utility models and are entirely compatible with Bayesian methods of inference and decision (Keeney and Raiffa 1976, French and Rios Insua 2000). These methods have been used in many applications and are implemented in many software packages, including RODOS (Bertsch et al. 2009). The Analytical Hierarchy Process (AHP) is another MCDA approach, based on less well explored assumptions (Saaty 1977, Saaty 1980). Critics point to certain paradoxical behaviours known as rank reversal (Belton and Gear 1983, Saaty and Vargas 1984); but others have noted that if used to assess weights only and not marginal value functions, such behaviours are not an issue (Salo and Hämäläinen 1997). When steps are taken to counter rank reversal, AHP and MAVT approaches are reasonably compatible. An entirely different set of approaches are based on outranking ideas (Roy 1996, Roy and Vanderpooten 1996). These lead to methods such as the ELECTRE family of approaches (Roy 1990) and PROMETHEE (Brans and Mareschal 2005). Again these methods have found many applications (Roy et al. 1993).

Outranking approaches are quite different to MAVT and AHP ones. They allow incomparability between options, non-compensatory approaches and the use of pseudo-criteria (implementing the concepts of indifference, weak preference and strict preference). They use some of the same technical terms with subtly but significantly different meanings. This can lead to confusion among stakeholders and, unfortunately, many analysts. For instance, all MCDA methods introduce 'weights' which measure the relative importance of different attributes *within the structure of their models*. So it is possible that two distinct MCDA methods might assign 0.7 weight to an attribute such as health impacts arising from radiation exposures. However, although the numerical value 0.7 is the same in both cases, the relative importance represented might be different. Weights of attributes cannot be compared simply across different MCDA models (Gershon 1984, Steele et al. 2009). This means that great care must be used when setting up a series of stakeholder engagements using MCDA methods to ensure that the methods employed use compatible concepts. Otherwise, far from becoming clearer on stakeholder values, we may in reducing one set of uncertainties introduce several others.

Using MCDA in stakeholder engagement workshops has allowed us to learn about certain stakeholders' values. MCDA cannot, of course, summarised the opinions of entire populations of stakeholders unless some care is taken to consider and ensure the representativeness of the participants. Representativeness, normally thought of as a governance issue, is also important in reducing ethical uncertainty and lack of clarity on values.

Conclusion

In planning for, managing and recovering from a radiological accident, there are many uncertainties that have to be assessed, analysed and communicated to emergency managers and stakeholders. Some may be modelled by probability, some explored and bounded through sensitivity calculations, and some relating to lack of clarity may be resolved by introspection and discussion; but some may be deep and allow only cursory assessment and analysis in the time available. There is no single methodology that enables analysts to address the myriad of uncertainties facing emergency managers. During the CONFIDENCE project, we have needed to draw on many approaches to cope with uncertainty for improved modelling and decision making in nuclear emergencies, and sought to ensure that the approaches we use are based on compatible sets of assumptions. Coherence and consistency are important.

Table 4 provides a summary of the different forms of uncertainty and approaches to modelling and analysing them.

Finally, we note that the European Food Safety Authority (EFSA) has produced extensive guidance on how to identify, analyse, present and communicate uncertainty. The report provides much complementary material to this paper which recognizes the imperatives and responsibilities on scientists providing advice to public officials and regulators (EFSA 2018).

Table 4: Summary of the different forms of uncertainty and approaches to modelling and analysing them

Uncertainty	**Examples**	**Approaches to modelling and analysing**
Stochastic (physical randomness)	• Occurrence and patterns of precipitation • Actual numbers and locations of the local population at the time of the release • Long term radiation related health effects	• Probability modelling and statistical analysis
Actor (human behaviour)	• Level of compliance with advice • Effectiveness of implementation of clean-up operations	• Probability modelling • Simulation and agent based modelling • Adversarial risk analysis
Epistemic (lack of scientific knowledge)	• Source term characteristics: time profiles of radionuclide mix, energy, etc. • Course and shape of plume and deposition	*Normal uncertainty* • Probability modelling and statistical analysis *Deep uncertainty* • Exploration of several scenarios
Judgemental (e.g. setting of parameter values in codes)	• Parameters within models and computer codes • Compliance of population with advice on protective measures	• Sensitivity analysis • Monte Carlo analyses
Computational (inaccuracy in calculation)	• Accuracy of approximations used in atmospheric dispersion and deposition models	• Bounds from numerical analysis • Probability modelling of error distributions if stochastic approximations or statistical emulation used
Modelling (i.e. however good the model is, it will not fit the real world perfectly)	• Discrepancy between model and reality if model based on accurate parameters and data and calculations performed perfectly	• Experience ….
Ambiguity, Lack of Clarity and Endpoint (ill-defined meaning)	• How should Endpoints be described, what matters • Importance of different attributes in evaluating endpoints	• Stakeholder workshops using facilitation to challenge thinking

Uncertainty	Examples	Approaches to modelling and analysing
Social and ethical (i.e. how expert recommendations are formulated and implemented in society, and what their ethical implications are)	• How expert recommendations are formulated and implemented in society • Acceptance of risk • Ethical issues: risk distribution, autonomy, governance, responsibility, transparency • Communication	• Social psychology, mental models, naturalistic observation • Ethical principles of radiological protection • Communication experiments
Depth of modelling	• Is the analysis sufficient to take a decision?	• Relies on judgement, though in the emergency phase may be driven by the urgency of the situation.

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APPENDIX B - Questionnaire for better understanding decision making

Questionnaire for better understanding decision making

First of all, thank you for taking the time to fill in this questionnaire and to support our work in CONFIDENCE with your expertise.

The goal of this specific task of CONFIDENCE is to better understand the decision making process, especially the fact that identical scenarios with some leeway in preferences may lead to different decision making. In this context we refer to decision making as the work of an advisory body and address the members of this advisory body as decision makers, even if they are not the actual (political) decision maker. In particular we are interested in the individual behaviour of the decision makers, the structure of the advisory body, its workflow, and the interactive negotiation between its members in case they do not initially agree on a subject.

The questionnaire contains 4 sections:

General Context

For this questionnaire we of the CONFIDENCE project do not need any of your personal data in general but are interested in your answers as experts. However it may be helpful for us to come back to you if we need to clarify your answers or ask for details. In such a case we would need to contact you e.g. by email.

It is optional to provide such a contact. If you do not want provide a contact please just fill in your answers without reference to any personal data. In case you want to provide a contact please read and fill in the consent below for the use of personal data by the CONFIDENCE project.

Consent

The operators of CONFIDENCE take the protection of your personal data very seriously. Under the terms of the Data Protection Act 1998 ("Act") and the General Data Protection Regulation 2016, I consent to the CONFIDENCE project using my personal data for the purpose of processing the questionnaire "Evaluating questionnaire for better understanding decision making".

I understand and agree that the CONFIDENCE project is the data controller and it will process my personal data for the above purpose and I consent to the following

1. CONFIDENCE will process the following data sets in respect of my personal data for the above purpose: Name, email
2. Store my contact details on its database in case CONFIDENCE needs to contact me for the above mentioned purpose.
3. Process my personal data within the EEA.
4. Retain my personal data until (strike inapplicable): end of the project / unlimited
5. CONFIDENCE will only disclose my personal data to members of the project.
6. You have the right to withdraw your consent at any time by contacting the CONFIDENCE management
7. More information about the GDPR is available here: https://www.kit.edu/dataprotection.php

CONFIDENCE will hold your personal data securely and keep it confidential at all times. The legislation gives you the right to access information held about you. Your right of access can be exercised in accordance with the legislation.

Questions, comments and requests regarding your personal data should be addressed to the CONFIDENCE management team.

Name (please print)……………………………………………..   email …………………………………………………..

Date ……………………………   Signed …………………………………………..

Your personal data in case CONFIDENCE wants to contact you. Please refer to the consent form on the previous page.

a) Your name

b) Your email address

Related to the questionnaire: if not in general applicable please mark your answers accordingly.

- Please state the country your answers are in general related to.

- Please state the phase (early, transition, late) of the accident your answers are in general related to. If required you may also directly tag your answers with the according phase.

Structure of Advisory Body

1. How many members does the advisory body have and who are they? Are they related to specific groups e.g. scientists, authorities, NGOs, operators? How are the groups formed? (example: 2-3 scientists, 1 county official, …)

2. Is the composition of the advisory body in organisations or individuals fixed or can it vary? If it varies can you outline in which way? Who has the responsibility? (example: at least 6 of 8 organisations have to participate, individuals are appointed just in time, …)

3. Are there legal laws, rules or guidelines how to establish the advisory body? What do they depend upon? (example: no, was fixed once by law; yes, flexible e.g. guideline for INES level below 3: no federal ministry members need to be involved, …)

4. Are there any additional influences or parameters that impact the structure of the advisory body and the chosen members, especially short term?

Decision Makers

5. Can you identify different types or groups of individuals respectively decision makers? (example: scientist, county official, government advisor, emergency center operator, conservative, …)

6. Implicit type effects: Is a decision likely biased with a type of decision maker? That is by being a certain type do they <u>tend</u> to act in a certain way? (example: government employees rather recommend shelter when in doubt)

7. Explicit type effects: Is a decision mandatorily biased with a type of decision maker? That is by being a certain type do they <u>have</u> to act in a certain way? (example: facility operators have to care a lot about costs, government employees have to have high preference for security)

8. Are decision makers constant in their decisions? Are decisions rather predictable or uncertain, disregarding uncertain decision criteria? (example: government employees come in general to the same conclusion when presented with the same scenario multiple times)

9. Are there unspecific conditions affecting decision makers? If so in what way? (example: in early hours (=tired) it takes longer to provide a decision)

10. Can you describe in your own words why the decision makers do not come to the same conclusion? What can be the reasons for them to judge scenarios differently?

11. In case of contradicting opinions and no conclusion is found, is it acceptable to weight expert opinion, and if so how should this be done?? Can decision makers be ranked e.g. by “expertise” or “qualification”? (example: years of job experience, publications, …)

Regarding Input for Decision Making (Table see next page)

12. Apart from safety (e.g. dose thresholds) aspects, what are the most common criteria taken into account to make a decision? (example: costs, available time, acceptance, weather reliability, …)

13. If preferences exist can you provide a preference ranking on the criteria for each decision maker group (example: costs "more important than" acceptance or in absolute weights from 1=least to 10=most important (e.g. costs=9, acceptance=5)

14. Which of the considered criteria are static and which are dynamic and not fixed beforehand? (example: static: accident type, intervention levels, … dynamic: duration of action, time of day, …)

Table summarizing questions 12 to 14

Less criteria are better than more. Keep them limited to less than 10 at most Criteria should be distinct and not overlapping with others.

Criterion	Importance	Static/Dynamic	Value Range	Comment/Description

Process of Decision Making

15. Please describe briefly the workflow of the decision making process from your point of view. (example: data acquisition, apply decision support tools, decision makers individually conclude, discussion in group, finally a majority vote concludes decision, frequency of meetings, discussion of uncertainties, regularity of updating of advice with changing situation)

16. Is the decision process split in sub tasks, respectively do sub groups work on independent parts of the overall decision?

17. Is the decision process split in multiple stages? (example: yes, sub groups prepare and rank possible decisions, the full group reconsiders and filters the suggested decisions)

18. What is the result of the decision making process? Is it a single recommended decision or a ranked list of various possible actions? Is a reasoning provided for the outcome?

19. Do pre-defined rankings or lists exist that define preferences on management strategies?

20. Are decisions delayed on purpose to gather additional information? Are decisions reconsidered regularly or stay fixed once made? (example: reconsidered after updated measurements)

21. Are uncertainties taken into account? How are they defined? Do they have different categories or types? (example: happens 4 in 10 times, normally distributed with parameters, nominal as in “likely”, “rather unlikely”)

22. Do decision makers rather discuss handling uncertainties and missing values or rather focus on the available and reliable data? (example: focus on prognosis results, ignore unconfirmed input measurements, …)

23. Are there general strategies for short term coping with missing input (example: ignore, delay decision, assume worst-best-average, …)

24. Are there strategies for short term coping with uncertainties (example: ignore, delay decision, assume worst-best-average, …)

25. Assuming a decision is made in consensus of all decision makers, how is it done? Is there a voting for the best decision? A negotiation or argument? Is the “experience” or “qualification” of members considered in the consolidation?

26. What happens if contrary opinions cannot be resolved, respectively the decision makers cannot come to a combined conclusion?

APPENDIX C - Report of the [Slovak] National Panel

This project has received funding from the EURATOM research and training programme 2014-2018 under grant agreement No 662287.

D 9.22 Part B-08

Stakeholder engagement through scenario-based discussion panels

Report of the [Slovak] National Panel

Released

Version 1.0

CONFIDENCE-WP4. Transition to long-term recovery, involving stakeholders in decision-making processes

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Duranova T.; Bohunova J. (VUJE)

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Work Package:	WP4	Transition to long-term recovery, involving stakeholders in decision-making processes (TRANSHESS)		
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Executive Summary

Stakeholder discussion panel have been set up in Slovakia in the framework of the project CONFIDENCE – WP4 (Transition to long-term recovery, involving stakeholders in decision-making processes) and WP6 (Decision making under uncertainties) to deal with decisions taking in the transition phase on urban decontamination issues and the impact of relocation as well as continuation of the previous activities related to establishing and assessing the processes for national dialogue with stakeholders during the transition to recovery phase, based on representative contamination scenario. The target of the discussions has been focussed on what to do and how to proceed in such contamination scenario and how to evaluate the potential impacts of decisions on achieving acceptable living conditions. The formal decision aiding tool such as multi-criteria decision making (MCDA) have been presented and tested during the stakeholder panel to see how it can be adapted and used for uncertainty handling and "robust" decision making for radiological emergency. These discussions were mindful of the inherent uncertainties associated with the real consequences of the contamination scenario, the strategies to be implemented and the potential socio-economic impacts on the affected population. Preferences collected within WP4 panel discussion served the inputs to the MCDA by WP6. The appropriate means of visualisation in terms of information for decision making when based on an MCDA tool have been discussed and evaluated.

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1 Objectives and Scope

The main objective of the panel was to facilitate stakeholders' involvement and to provide valuable input in the process of decision making to improve preparedness for and response during the transition phase.

The objective of the Slovak panel was to incorporate the views of the stakeholders in the governance of the exposure situation, taking into account the inherent uncertainties associated with:

- the real consequences of a contamination scenario,
- the goals and criteria influencing development of the recovery strategies,
- the strategies to be implemented,
- the potential socio-economic impact on the affected population and
- the preferences that should be incorporated in the multi-criteria decision-making (MCDA).

The main areas of interest were evacuation/relocation of population and urban area recovery. In that sense the objectives were focusing on following issues:

- To determine which criteria are important for which stakeholder groups;
- How certain criteria impact the return of evacuated/relocated population or opposite – impact further extended evacuation/relocation;
- How these criteria and their uncertainties could be taken into account in post-accident decision making on decontamination and recovery management.

2 Methodology

The seminar with stakeholders from already established national panel invited to participate in the CONFIDENCE project activities and workshops took place in VUJE premises in February 8, 2018 with the main goal to introduce CONFIDENCE project objectives and particular tasks of the WP4 (Transition to long-term recovery, involving stakeholders in decision-making processes), WP5 (Social, ethical and communicational aspects of uncertainty management) and WP6 (Decision making under uncertainties) and their interaction. The date and duration of workshops as well as WP4 questionnaire have been discussed to collect the ideas of experts and stakeholders on issues to deal during the transition phase.

Stakeholders have been informed about the surveys and interviews planned to be conducted within work-packages WP4-WP6 and Delphi study and their importance in terms of fulfilment of project objectives.

Active participation of Slovak stakeholder in all tasks provided basis for the scenario preparation. First Delphi study results have been presented at the NERIS Platform workshop in Dublin, April 2018 and also at the national Slovak stakeholder panel.

It was agreed to have two two-days combined panels organized by VUJE in VUJE premises in Modra-Harmonia:

1) first in December 10-11, 2018 (WP4+WP6) and
2) second in March 4-5, 2019 (WP5+WP6+WP4).

The aim of first workshop was through open facilitated discussion on criteria in decision-making and uncertainties to get and prioritize stakeholder preferences on criteria and alternatives of countermeasures that should be incorporated in the MCDA tool, its testing and use as a decision aiding tool.

The stakeholder dealt with urban decontamination issues and the impact of relocation was treated.

2.1 Scenario and timeframe of interest

2.1.1 Contamination scenario

The scenario was situated during the transition phase after a fictitious nuclear accident in the Bohunice NPP with external release of radioactivity to environment. The release has ceased, and the control over the source has been taken. The radioactive contamination has spread in the surroundings of the damaged NPP and transported and dispersed through the borders of the country affecting the neighbouring regions. Early emergency actions have been taken to avoid the exposure to population, including evacuation, access restrictions and food restrictions. It has to be decided how to proceed in such a situation and prepare recovery of contaminated areas.

Following figures are presenting ground contamination, areas affected by evacuation and temporary relocation.

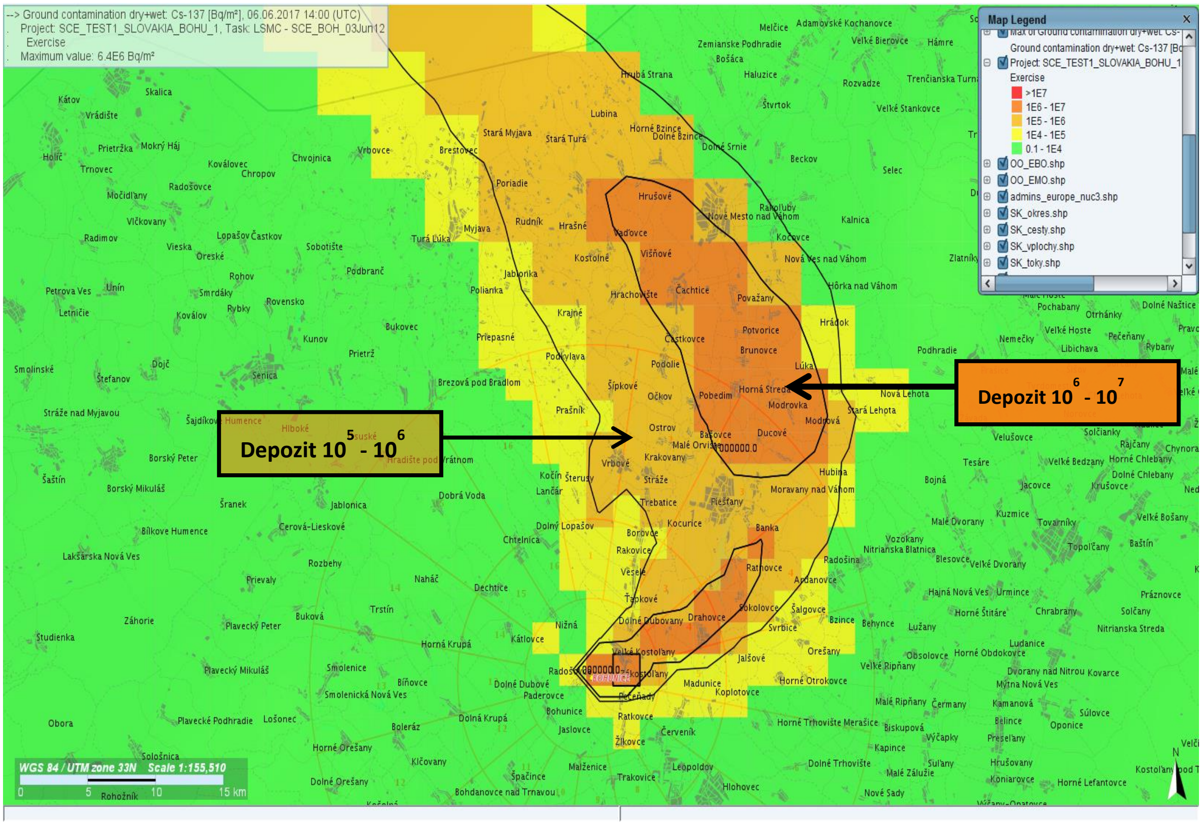


Figure 6: Scenario Bohunice (release: June 3 at 12:00) ground contamination (dry+wet) for Cs137 at ~3 days after start of release

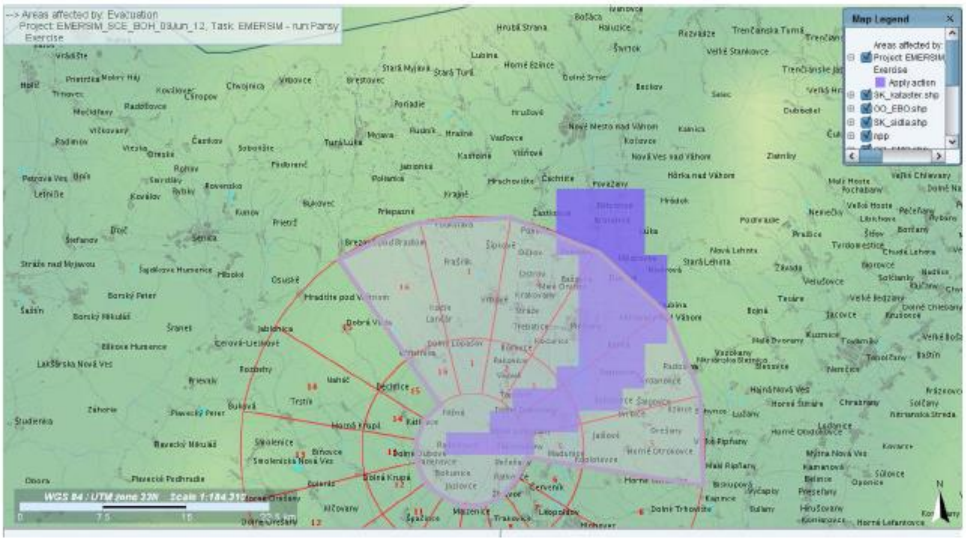


Figure 7: Areas affected by evacuation (effective dose, integration time 7 days, 100 mSv)

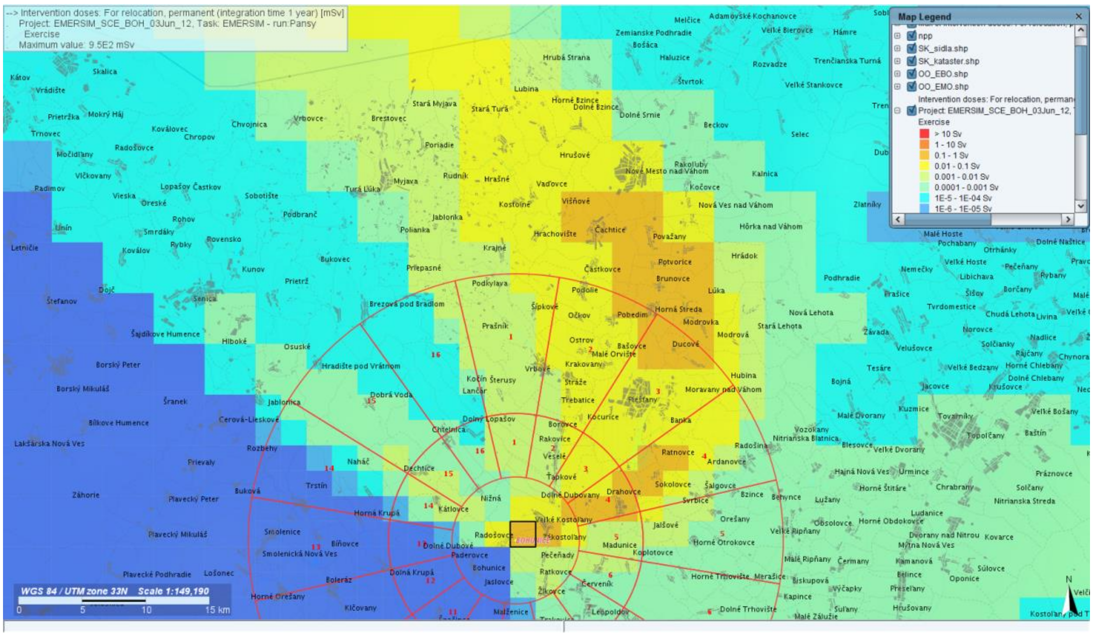


Figure 8: Areas affected by temporary relocation (effective dose, int. time 1 year, 100 mSv - GSR Part 7)

2.1.2 Case study: urban issues in Piestany

Municipality Piestany, spa town within the Trnava region, Piestany district was the main area for the discussions. The Piestany population is about 27666 citizens and in addition 6 000 spa guests. The area of municipality is about 44.2 km^2 with 24% of build-up area ~ 10.7 km2 including buildings with different walls and roofs, interiors, streets and pavements, areas of grass, trees, plants, soil, playing grounds, sport fields, water areas and others.

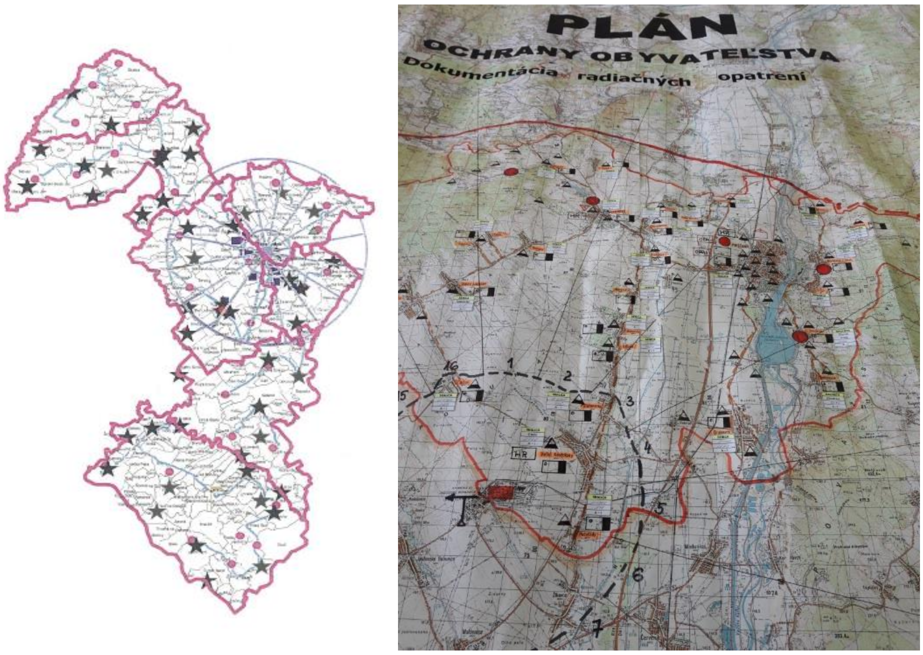


Figure 9: Region Trnava, District Piestany

Municipality Piestany is situated on the right bank of the river Vah south of the town is the Slnava water reservoir created by a dam on the Vah river.

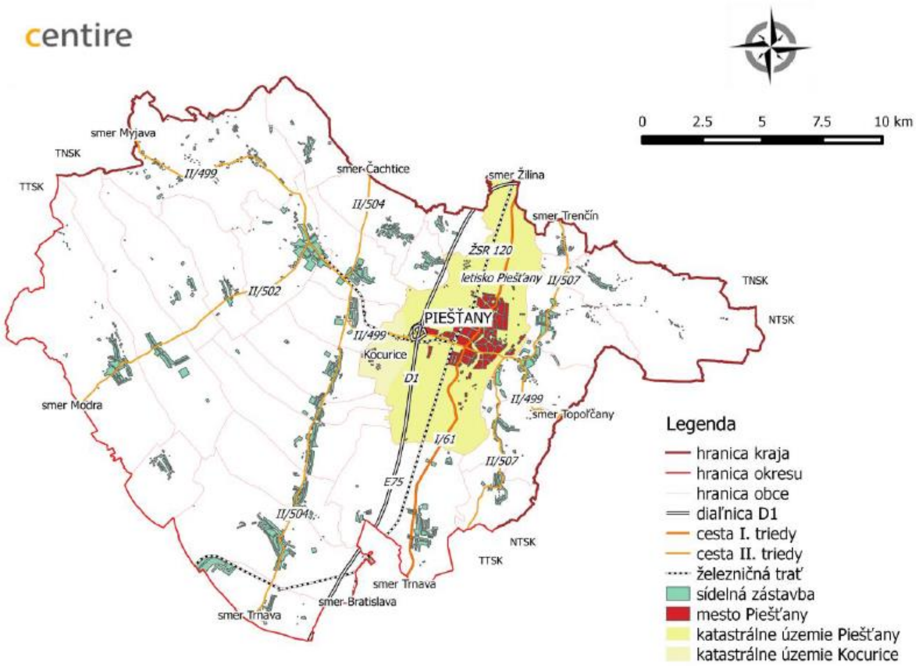
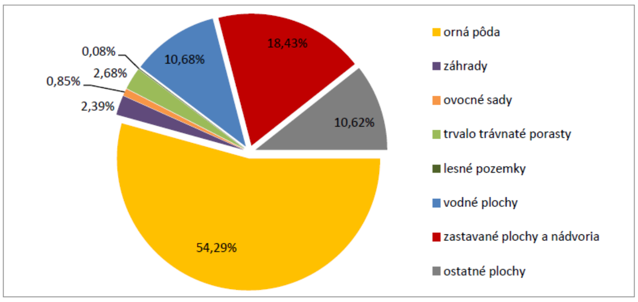


Figure 10: Location of District Piestany

Under the scenario the situation in Piestany 3 days after an accident was supposed to be as follows:

- Contamination 3 - 4 MBq/m^2 137Cs
- Doses ≈ 20 mSv/year



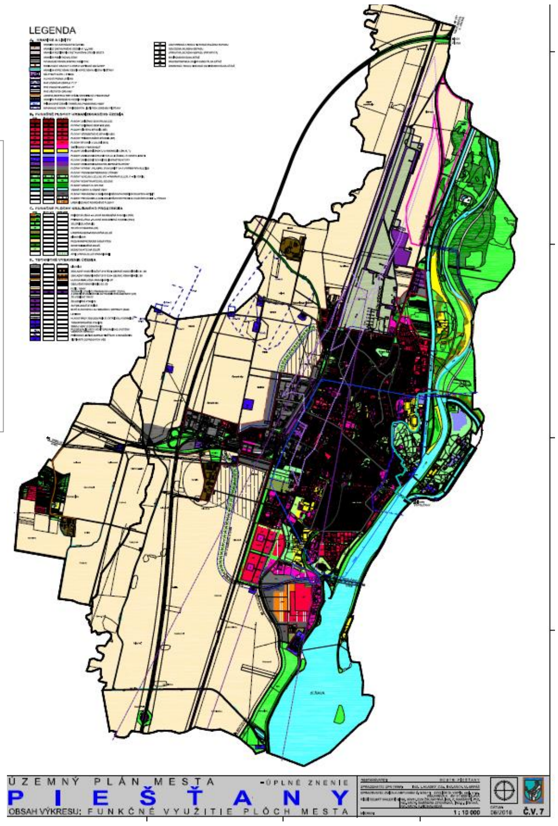


Figure 11: Municipality Piestany, urban area composition

As under the scenario panel was gathered for the discussion 3 days after the accident, aspects and information about the daily life issues and plans have been prepared as well.

Traditional events in Piestany during summer - period in 3 month after an accident:

- 1.– 3.6.2018 Opening on the spa season
- – 3.6.2018 International Canoe Regatta Piešťany - International event for the young canoeists
- 15. – 16.6.2018 Car at tuning party – party motorisms, sport, music, dance, fashion and entertainment
- 6. – 8.7.2018 Motorcycle race with side rock concerts, paragliding and other site events
- 10. – 11.8.2018 Grape Festival is a summer music open-air festival
- 30.8. – 1.9.2018 Country Lodenica – a festival dedicated to country and folk music
- 17. – 23.9.2018 Victoria Regia is the major florist event in Slovakia – an international competition in flower arranging. The annual Slovak championship in flower arrangements and traditional flower promenade are enriched by Unusual Flowers Festival

2.1.3 Recovery strategies

Eight strategies have been defined based on the EU project HARMONE. Five strategies with different recovery options aimed at the cleanup of areas of grass, soil and plants, the interior and roofs. Three of the five cleanup strategies were combined with a three month relocation period.

1. Do nothing (introducing of monitoring strategy)
2. Grass cutting, vacuum cleaning (roads)

3. Roof brushing (roofs), vacuum cleaning (internal building), tree/shrub removal (trees and shrubs), grass cutting (small and large areas of grass), plant and shrub removal (small area of plants) (*low waste 1*)
4. Roof brushing (roofs), vacuum cleaning (internal building), tree/shrub removal (trees and shrubs), grass cutting (small and large areas of grass), plant and shrub removal (small area of plants), rotovating carried out after plant, grass and shrub removal (*low waste 2*)
5. Roof replacement (roofs), vacuum cleaning (internal building), tree/shrub removal (trees and shrubs), grass cutting (small and large areas of grass), plant and shrub removal (small area of plants), topsoil removal carried out after plant, grass and shrub removal (*high waste*)
6. Roof brushing (roofs), vacuum cleaning (internal building), tree/shrub removal (trees and shrubs), grass cutting (small and large areas of grass), plant and shrub removal (small area of plants) (*low waste 1*) + relocation for three months
7. Roof brushing (roofs), vacuum cleaning (internal building), tree/shrub removal (trees and shrubs), grass cutting (small and large areas of grass), plant and shrub removal (small area of plants), rotovating carried out after plant, grass and shrub removal (*low waste 2*) + relocation for three months
8. Roof replacement (roofs), vacuum cleaning (internal building), tree/shrub removal (trees and shrubs), grass cutting (small and large areas of grass), plant and shrub removal (small area of plants), topsoil removal carried out after plant, grass and shrub removal (*high waste*) + relocation for three months.

The results of ERMIN module of JRODOS system have been used as a basis for discussion.

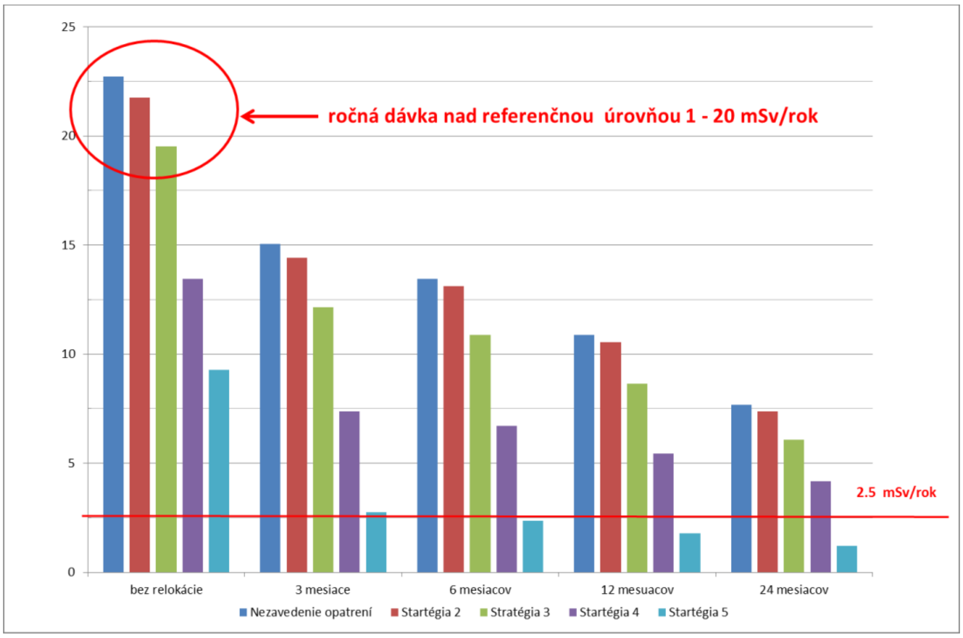


Figure 12: First year dose, mSv: without relocation; 3, 6, 12 and 24 months of relocation

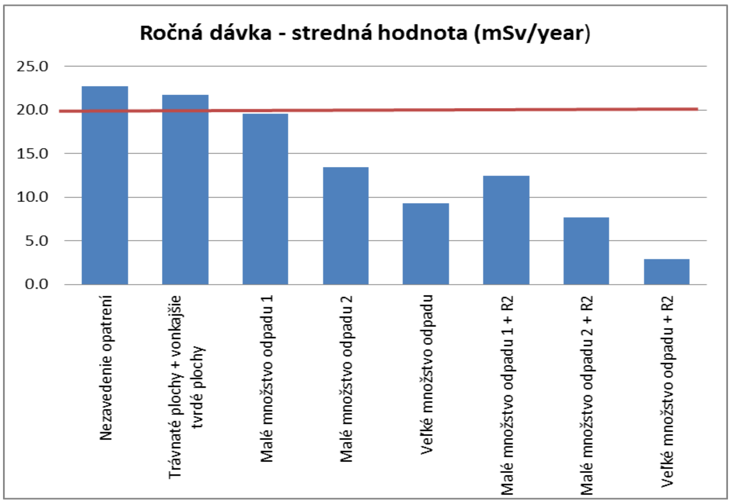


Figure 13: Annual dose, mean value, mSv/year

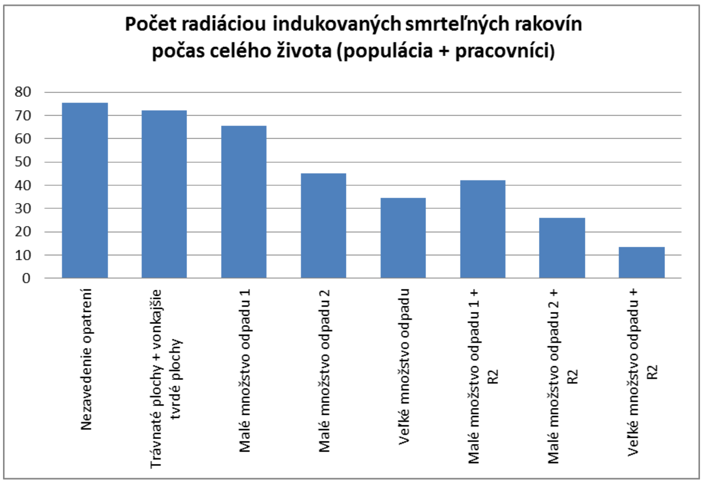


Figure 14: Number of cancer incidences during 50 years, attributed to the exposure (population and workers)

Figure 15: Radioactive waste amount, kg

Costs of countermeasures taken into account during the discussions included following items: accommodation during relocation, compensation of loss of productivity during relocation, clan-up strategy implementation, waste transport and storage and cancer treatments.

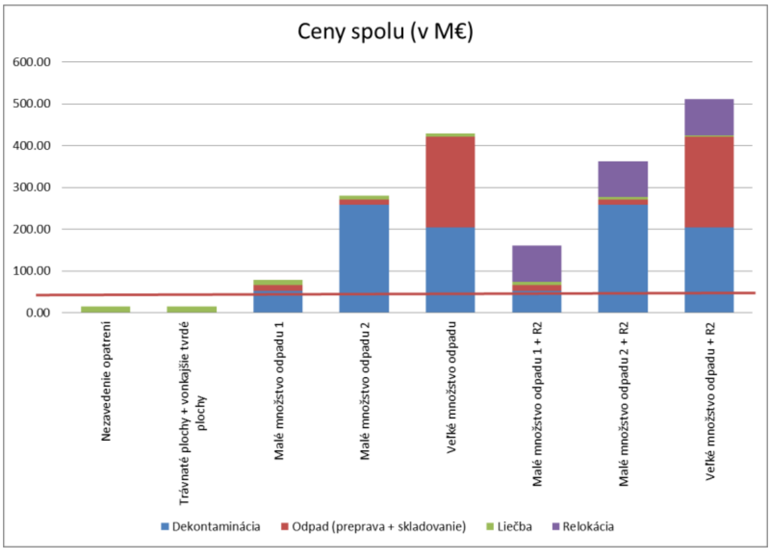


Figure 16: Overall costs for particular strategy

The following uncertainties have been included in generating the ERMIN outputs presented below: occupancy variability, deposition amount and composition to reference surface variability, shielding/environment variability, soil migration variability and countermeasure uncertainty (simply treated; time of application and whether or not effective).

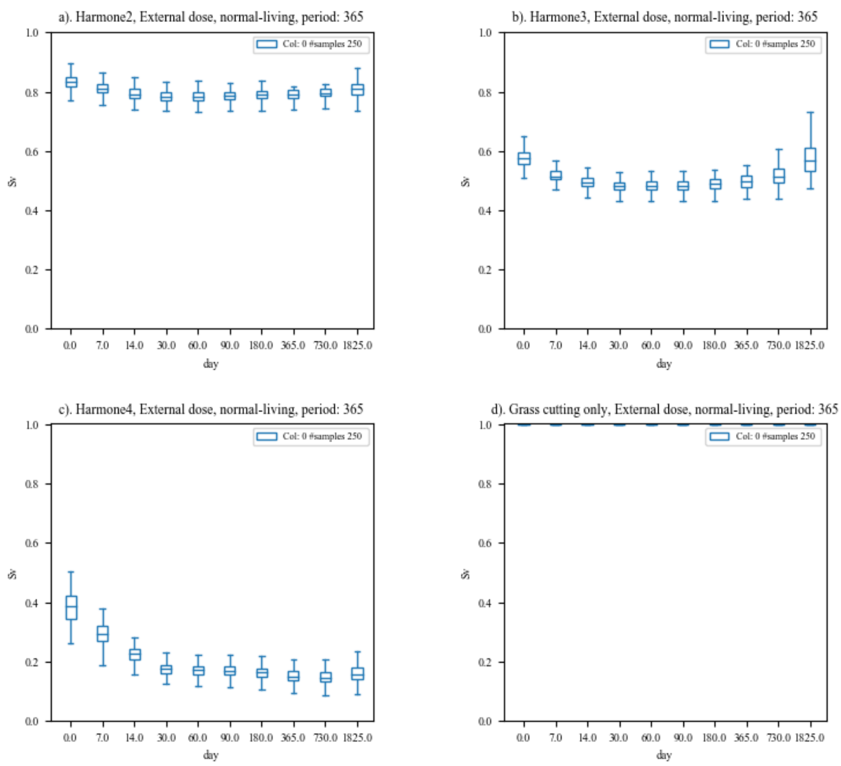


Figure 17: Dose reduction factors (Sv) for clean-up strategies (3, 4, 5, 2 - only grass cutting)

Uncertainties not included have been following: retention on other surfaces (e.g. because of different materials), variations in relative deposition to other surface (e.g. because of different materials), particle groups (e.g. varying proportions of fuel particles present) this can be expected to be correlated with distance.

2.1.4 Topic addressed

The addressed topics for discussion were following:

1. What do we understand by "the transition phase"
2. Main concerns during the transition phase
3. Issues to be addressed during the transition phase:
    a. Relocation of people and restoration of living conditions
    b. Application of countermeasures
    c. Decontamination
    d. Radiological characterization of the contaminated areas
    e. Radioactivity surveillance/monitoring programs
    f. Waste management
    g. Information and risk communication to the population
    h. Public acceptance
    i. Public trust in experts and authorities
    j. Stigmatization
4. Objectives and criteria of the restoration plan
5. Alternative restoration actions
6. Key criteria for the selection of management options
7. Stakeholders engagement
8. International cooperation

2.2 Organization and schedule of the meetings

The Slovak stakeholder panel took place in December 10-11, 2018 in VUJE premises in Modra-Harmonia. The participants have been accommodated in the VUJE resort.

Framework programme of the workshop was following:

10.12.2018 (Monday)

- Participants arrival, registration, accommodation, coffee, tea, refreshment
- Introduction - project CONFIDENCE (main goal, WP4 objectives, participation in the surveys, Delphi study), BSS requirements, management of contaminated inhabited areas (EURANOS Handbooks), the main goal of the workshop, programme and agreement on way of work (*Tatiana Duranova*)
- Requirements and criteria on protective measures under the valid legislation (the new radiation protection law related to BSS requirements) with focus on transition from emergency to existing exposure situation after the nuclear accident, discussion (*Public Health Authority representative*)
- Facilitated discussion (*Tatiana Duranova*) - warming up, inherent uncertainties on the knowledge of the real consequences:
  Radiation protection of population in the transition phase of nuclear accident
    - What do we understand by "the transition phase",
    - Main concerns and most important difficulties during the transition phase,

- Issues to be addressed during the transition phase (evacuation, relocation, application of countermeasures, monitoring - health and radiological characterisation o the contaminated area, decontamination, waste management, information and work with population - risk communication, public acceptance and public trust in experts and authorities and other),

- Introduction to the workshop scenario (*Jarmila Bohunova*)

- Scenario: Case study - Countermeasures in Spa city Piestany after the NPP Bohunice accident (*presentation - Jarmila Bohunova and follow up discussion facilitated by Tatiana Duranova*)
  - Objectives of the recovery/restoration plan: Which objective do we need to achieve? (Dose levels restored, minimum impacts in the population, public confidence, minimum economic costs, minimum environmental impacts, etc.)
  - Alternative restoration actions: relocation, do nothing, strategies - low waste, high waste, simple and quick to apply and difficult and slow)
  - Key criteria for selection of strategy (evaluate management options, discuss possible decisions, prepare input for MCDA)
  - Stakeholders engagement (Is it necessary? Preferred role - in decision making, other? What kind of stakeholders need to be involved? How to involve? Roles and responsibilities? Are they clear? Coordination?
  - International cooperation (Is it well established?)

11.12.2018 (Tuesday)

- Summary of key findings from the discussions at previous day (*Tatiana Duranova*)
  - Objectives of the recovery/restoration plan,
  - Alternative strategies,
  - Key criteria for the selection of strategy
- Introduction to the MCDA and taking into consideration uncertainties in decision making about protective measures within the transition phase (*Tim Mueller, simultaneous translation by Tatiana Duranova*)
- Discussion about choosing/prioritise the strategy (use of MCDA) and taking into account the inherent uncertainties on:
  - the knowledge of the real consequences of an accident based on exercise scenario,
  - goal and criteria during the development of strategies on protective actions and their implementation
  - the strategies to be implemented, and
  - the potential socioeconomic impact on the affected population)

- There are many uncertainties involved in topics discussed. Examples of uncertainties are those associated with:
  - The radiological situation of the scenario contributing to the overall uncertainty associated with the estimated impact:
    - Space-time evolution of the contamination and the prediction of the radiological situation in the long term
    - Results of the monitoring
    - Possible changes in the future use of the scenario
  - The goals and criteria used in the design of the protection strategy:
    - Objectives pursued
    - Radiological criteria: reference levels

- Indicator Units (time to carry out the implementation of the strategy, area affected, nº of persons affected…..)
- The protection strategy regarding:
  - Effectiveness
  - Side-effects
  - Generated wastes and their disposal
  - Costs
  - The design of the recovery strategy, is sufficiently flexible and adaptable to take into account the evolution of the radiological situation?
- The social pressure regarding:
  - Trust and confidence: Will the protection strategy really allow the resumption of social and economic activities; stigmatization of the affected area
  - Acceptability of the recovery actions
  - Conflicting interests among the affected population and/or affected economic activities of the affected area

- Continue in discussions about preferences while choosing of strategies and uncertainties.
- Presentation of the results of the first round of Delphi study: identification of critical aspects of transition phase of an accident with experts and stakeholders (*Tatiana Duranova*).
- Finishing of workshop.

3 Composition of panel (participants)

19 members of Slovak national panel took part in the workshop. They represented following organizations:

- Nuclear Regulatory Authority (NRA SR)
- Public Health Authority (PHA SR)
- Civil Protection and Crisis Management Offices at national (Ministry of Interior – Civil Protection and Crisis Management Division) and regional level (Trnava region - Bohunice NPP, Nitra Region - Mochovce NPP)
- Slovak Medical University in Bratislava (monitoring network and education)
- Police Academy (Public Administration and Crisis Management)
- Slovak Hydrometeorological Institute (monitoring network)
- Mayor and Chief of self-government (Prefect) of village Kalna nad Hronom (member of GMF – Group of European Municipalities with Nuclear Facilities and national Association of Municipalities and local/regional Civic Information Commissions, Mochovce NPP area)

The panel was composed of usual decision-makers involved at different levels of the emergency preparedness, response and recovery management activities.

4 Results analysis and main issues identified

4.1 Concerns, difficulties and uncertainties during the transition phase

Requirements and criteria on protective measures under the valid legislation (the new radiation protection law related to BSS requirements) with focus on transition from emergency to existing exposure situation after the nuclear accident have been presented by Public health Authority as an introduction to the discussion.

The transition phase is defined in the Decree of the NRA about the emergency planning details and it is characterised by terminating of radioactive release from the nuclear installation. Population is affected in that phase of an accident primarily by external exposure from the contaminated surfaces or by internal exposure due to inhalation or consumption of contaminated food and water.

The main concerns and most important difficulties during the transition phase have been discussed as well as issues to be addressed during the transition phase with focus on: evacuation, relocation application of countermeasures, monitoring - health and radiological characterisation of the contaminated area, decontamination, waste management, information and with population - risk communication, public acceptance and public trust in experts and authorities and other.

The discussion could be summarized to following items with the source of uncertainty identified at the end of each item.

- Under the new radiation protection law the corresponding Regional Public Health Authority (RPHA) in cooperation with other Ministries has competence to order the protective measures in the emergency situation; territorially the corresponding regional authority within the territorial district of Trnava and Trencin region is PHA SR (national level), therefore representatives of the Division of health protection against irradiation from PHA SR are sent to be part of the Regional Crisis Staff during the radiological accident.

  Uncertainty: Is personal resources of trained and prepared professional at PHA SR sufficient?

- As the PHA SR has no their own tools and decision support systems they are collaborating with NRA SR which has Decision support systems (JRODOS, RTARC) for the independent assessment of the accident consequences and preparation of advice for the urgent countermeasures. The complex decision support system JRODOS provide tools and support for the assessment of the countermeasures in the later phases of a radiological accident.

  Uncertainty: Is competence in use of complex decision support system for preparation of later phases of accident countermeasure advice adequate?

- Among others the iodine prophylaxis is one of the urgent countermeasures. The KI tablets are pre-distributed within the emergency planning zones in Slovakia. There was a problem during the last exchange campaign which was caused by change in the KI tablets supplier by NPP (change from Slovak supplier to the Austrian one), their distribution (6 tablets in a box instead of 4 as usual) and also by discrepancy of instructions in a leaflet in relation to the legislation and procedures in the Slovak Republic (who has to take KI tablets, age limit, dosage). This brought additional demand on Ministry of Interior representatives at all level participating in tablets distribution via Civil Protection offices to population and brought additional uncertainty and doubt in population regarding taking KI tablets.

Uncertainty: Are KI tablets taken by all members of population within the emergency planning zone during the pre-distribution campaign?

Uncertainty: Is information on iodine prophylaxis and its effectiveness sufficient?

- Radiation monitoring competences are given under the radiation protection law. Current situation of radiation monitoring network is characterized by break-up of resources (personal and technical) and require taking immediate decision. There is insufficient capacity of radiation monitoring network. The change in legislation which caused changes in the mode of operation from permanent to an emergency of many of radiation monitoring units under different Ministries caused the shortness to the unacceptable minimum in resources required for the maintenance and operation of the radiation monitoring.

Uncertainty: Is radiation monitoring network sustainable?

Uncertainty: Is there a gap between legislation and reality?

The decision on implementation of advised countermeasures is made by the authority/body at the Civil Protection Division at different level and it is taken into account not only the level of radiation but also feasibility of countermeasure, countermeasure implementation impact and other economic, social and other factors. The ordered countermeasures could not be implemented taking into account insufficient personal and technical resources.

Uncertainty: Are the available resources (personal and technical) adequate?

- The reference levels are given as a range of levels in the new legislation (1-20 mSv/year for existing exposure situation and 20-100 mSv/year for the emergency exposure situation. The value in particular emergency situation could be lower as it is given. How much is ”less than 100 mSv/year”? PHA is responsible to determine the particular reference level during the emergency situation for optimalisation of radiation protection. The analyses of possible emergency situations are part of the strategies of accident management where reference levels have to be established for each type of emergency situation. PHA should precise reference levels and includes them in the National emergency plan for the nuclear or radiological accidents which is under development and responsibility of the Ministry of Interior.

Uncertainty: Are reference levels well established?

Uncertainty: Is National emergency plan available and up-to-date?

- Evacuation has been discussed from the point of view of its ensuring and time when it has to be implemented in relation to the recommendation on sheltering lasting not longer than 48 hours. The planned evacuation with the evacuation speed 3000 people for hour is not possible to manage. The term of “immediate evacuation” has been discussed from the point of view of criteria for decision making on countermeasures with the main goal to avoid or minimize deterministic effects of radiation. Additional discussions and consultations between NRA SR and PHA SR are needed to further precise the definition and criteria for immediate/early/timely evacuation. It was stated, that today anybody will guarantee that evacuation will be implemented up to the 24 hours after its ordering.

Uncertainty: Is immediate evacuation ensured and feasible?

- The flexible change of the evacuation routs due to change in the meteorological conditions is not adequately ensured. The competences of particular region or district are their exclusive competence. It is not possible to intervene to those competences appointed and determined in advance. It is not possible to plan flexible use of evacuation routs under the changes in meteorological conditions what could lead to the needless exposure of evacuees during the evacuation using contaminated roads.

  Uncertainty: Is change in meteorological situation appropriately taken into account?

  Uncertainty: Are competences of regions/districts flexible in using of the evacuation routs?

  Uncertainty: Is there preparedness on flexible change of evacuation plans at place?

  Uncertainty: Are there backup office places of the Crisis Staff at regional or District level available?

- Food ban countermeasure dealing with food, milk, drinking water and food chain and water supply are implemented when clean substitute food, milk, drinking water or other alternatives are available.

  Uncertainty: Are food security measures ensured adequately?

- Transition phase determination or its exact definition is not given in the law on radiation protection. The transition phase could be understood as when prevailing existing exposure is in place as a consequence of emergency exposure situation. For the existing exposure situation the reference levels 1-20 mSv/year are valid. Withdrawal of the urgent protective measures such as sheltering, evacuation and relocation is justified when effective dose for the time of follow-up 12 months after the withdrawal of countermeasure will be lower than 20 mSv. These terms and criteria should be precise taking into account the phases of an accident from the point of view its time development.

  Uncertainty: Is the period of time identifying the transition phase after an accident unequivocal?

  Uncertainty: Are the criteria for implementation and withdrawal of countermeasures in transition phase unequivocal?

4.2 Case study discussion: alternative strategies, key criteria for strategy selection, uncertainties, stakeholder preferences

The presentation of case study focusing on Piestany presented in the Chapter 2 of the current report prepared the floor for the thorough discussion of the objectives of the restoration plan, alternative restoration actions and key criteria for selection of strategy.

The uncertainties identified in the general discussion have appeared again and have been specified in more details taking into account information available from scenario.

Figure 18: Discussion on alternative restoration actions and key criteria for strategy selection

The particular issues to be addressed during the transition phase and alternative restoration actions have been discussed as follows:

- All actions in Piestany (planned, prepared and scheduled) will be cancelled as minimum for the period of two months. Further operation of Spa Piestany is conditioned by return of population back to Piestany. While citizens will not return home any Spa guests will not come. While infrastructure will not be ensured in the city, the return of citizens back will not be possible.
- Information of population is a key issue. The information campaign should be focused on the situation development, decision making and procedure how to deal with the situation. The explanation of the situation (what happened) and communication with population should avoid rumors and baseless information. Trustworthy information should be provided taken from the unified information center to avoid contradictory and conflicting information. The information should be provided at different levels by entrusted persons. The secretary of Crisis Staffs at different levels should collect and share information with all involved and entrusted stakeholders. The communication should be open, based on facts and verified information and should not be excessively optimistic and giving false hope. In case of break of their promise the loss of trust could come.
- During the evacuation the mayors and prefects as well as members of self-government offices of villages/towns/cities receiving coming evacuees will take care of them. Part of evacuees will be received by relatives living out of the affected area. Evacuation could last 7 days under the law and will persist up to the withdrawal. The question is how long it could be. Temporary relocation should be justified and communicated with the mayor of village/town/city.
- Temporary relocation will ensure District Office in cooperation with Central Crisis Staff (national level) in relation to the organizational, technical and also financial aspects. Financial security will be very demanding.
- During temporary relocation but also during the evacuation the maintenance and operation of factories/objects which could not be closed. The mayor or prefect is responsible in cooperation with PHA as the shift changes should be monitored.
- The areas where evacuation or temporary relocation will take place should be secured by police; the area should be defined and closed to avoid plundering. Will there be enough of personal and technical resources?

- The issue of the animals left after the evacuation is complex and should be in the competence of the veterinary administration. In case of animals death the place for their burial should be established. The question of valuable animals and what to do with them is open. Uncertainty is also in the responsibility, who will do it.
- Monitoring of the environment, its complexity and ensuring is the key issue in the course of all actions. It is necessary to know the level of contamination, effectivity of countermeasure implementation and in answering question if citizens could come back home.
- Population should be informed about advised countermeasures, about possibilities and procedures of decontamination. The goal is the health of population and that they can return home as soon as possible.
- Regarding the decontamination the major issue will be availability of personal and technical resources. If volunteers will take part in decontamination they should be instructed and informed also have particular skills, Workers participating in the decontamination should give informed consent taking into account risks which can occur during the decontamination. It should be taken into account that they can refuse to perform the work. In case of technically demanding measures and procedures there will be again the question of availability of personal and technical resources. Will army cooperate with their resources? Who will pay?
- The financial security of implementation of all measures and actions is the key issue. Who will pay? Will insurance of population valid? What about the insurance of NPP?
- The role of Central Crisis Staff (national level) and Division of Crisis Management and Civil Protection at Ministry of Interior is crucial and irreplaceable as they have access to concrete information about availability of resources (personal and technical) from the whole Slovak Republic. They will prepare decisions on return of population back home in collaboration with PHA.

Based on this discussion which identified particular factors and uncertainties influencing strategy preferences participants ranked strategies as follows:

1. Strategy 2
2. Strategy 4
3. Strategy 3
4. Strategy 1
5. Strategy 6 + 7
6. Strategy 5 + 8

4.3 MCDA inputs: key criteria for strategy selection, stakeholder preferences

At the second day of the panel the criteria for selection of strategy have been summarized by facilitator.

Participants further discussed and identified key criteria for selection of strategy as follows:

- **Public health (health effects)** expressed in terms of doses or number of averted cancers caused by radiation from accident
- **Costs (economical effect)** expressed as a sum of costs on accommodation during relocation, compensation of loss of productivity during relocation, clan-up strategy implementation, waste transport and storage and cancer treatments
- **Personal and technical resources** subdivided into the number of workers needed for the realization of countermeasures, personal resources expressed by **"How difficult is to allocate the workers"** for particular restoration strategy implementation and technical resources needed for particular restoration strategy implementation
- **Wastes** expressed by availability of storage places which is conditioned by the **amount of waste**
- **Population acceptance and willingness to cooperate in realization of options of particular restoration strategies (self-help)**, attitude to the property and home, relation to receiving society during the relocation (stigmatization) and to certain degree indifference of people in peace time and during the emergency preparedness process,
- Political decisions, the role of the state, education and professionalism,
- Infrastructure - drinking water, education (school system), services, what wil be provided and what is the timing.

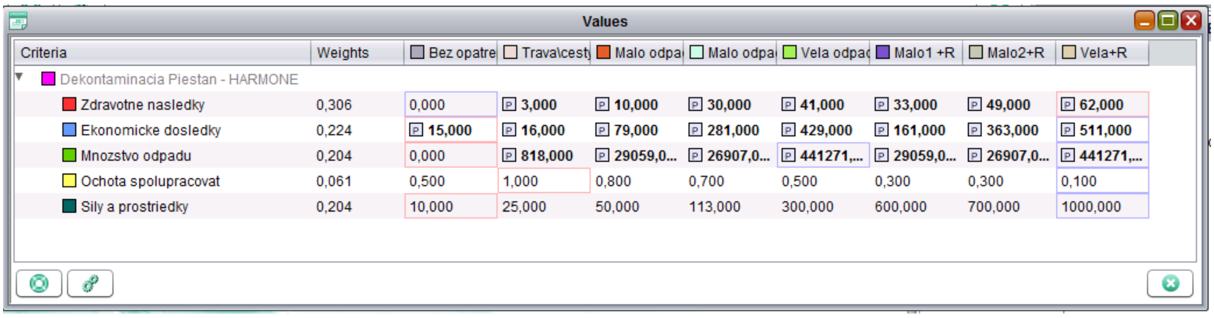
The MCDA system has been presented by Tim Mueller (KIT, Germany).

Participants agreed to choose the key criteria which will be used by MCDA which are presented in bold in previous paragraph.

Such criteria as health effects, costs and amount of waste have been used from the JRODOS results as an output of ERMIN calculations.

Soft criteria - expressed as "How difficult is to allocate the workers" and "Is population willing to cooperate in implementation" were widely discussed, precisely specified and expressed by empirical functions under the MCDA requirements.

The weights of particular criteria have been discussed and it was agreed that it is very subjective and responsible attitude is needed in their assessment. MCDA tool provide interface suitable to follow influence of the weights on the overall ranking of particular strategies and their preferences.


Values

Criteria	Weights	Bez opatre	Trava\cesty	Malo odpa	Malo odpa	Vela odpac	Malo1 +R	Malo2+R	Vela+R
Dekontaminacia Piestan - HARMONE									
Zdravotne nasledky	0,306	0,000	3,000	10,000	30,000	41,000	33,000	49,000	62,000
Ekonomicke dosledky	0,224	15,000	16,000	79,000	281,000	429,000	161,000	363,000	511,000
Mnozstvo odpadu	0,204	0,000	818,000	29059,0...	26907,0...	441271,...	29059,0...	26907,0...	441271,...
Ochota spolupracovat	0,061	0,500	1,000	0,800	0,700	0,500	0,300	0,300	0,100
Sily a prostriedky	0,204	10,000	25,000	50,000	113,000	300,000	600,000	700,000	1000,000

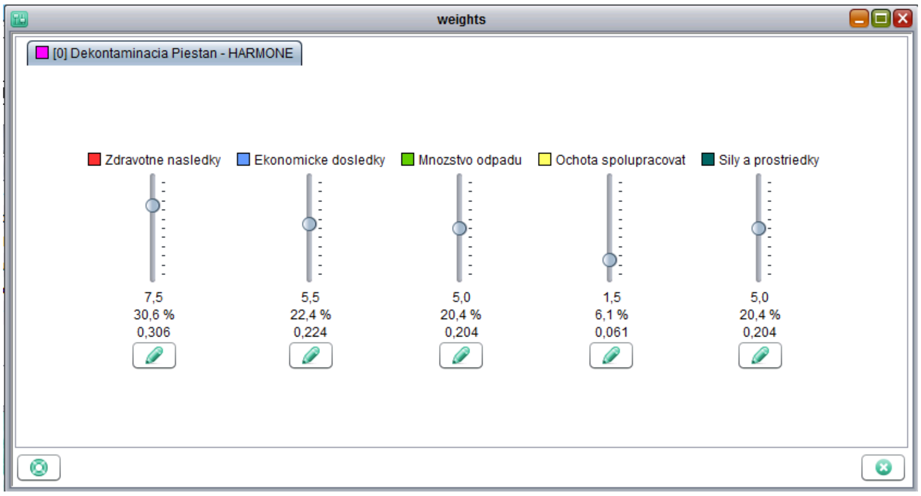


Figure 19: Criteria and their weights in MCDA

Taking into account all inputs the MCDA tool provided the output with strategies presented in a form of bars with contribution of particular criterion expressed by different color. The most acceptable strategy has the higher bar, the less acceptable strategy has the lowest bar.

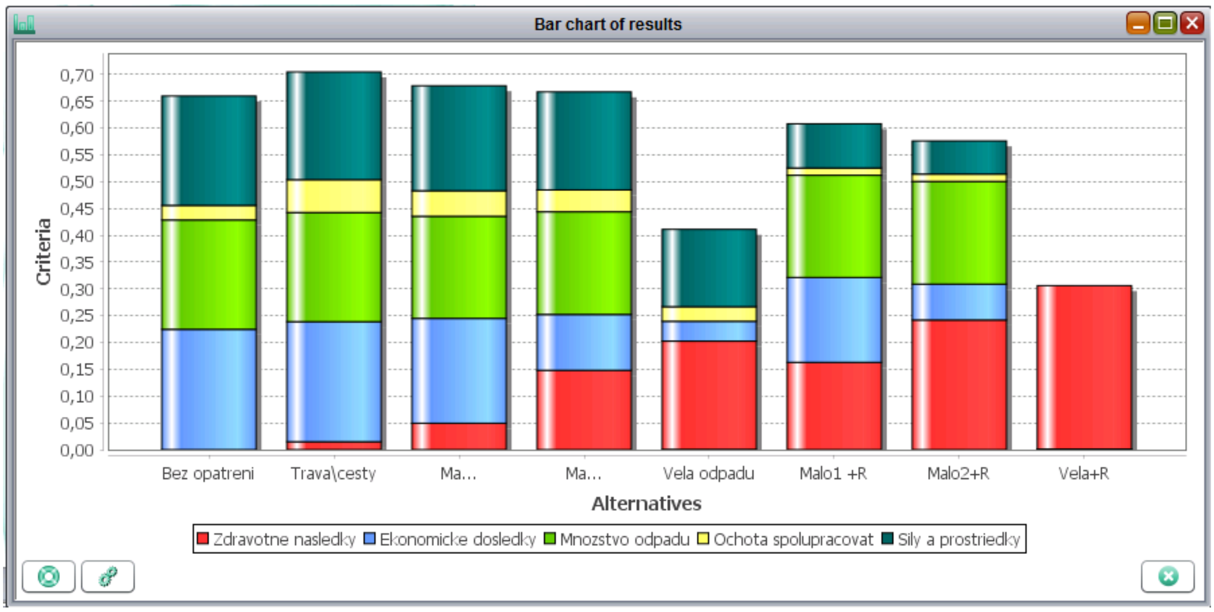


Figure 20: Preferences of particular restoration strategies by - MCDA output

It was stressed that MCDA tool is the aiding tool and its output has to be taken as supporting and it will not substitute final decision.

The different possibilities of outputs visualization have been presented and discussed.

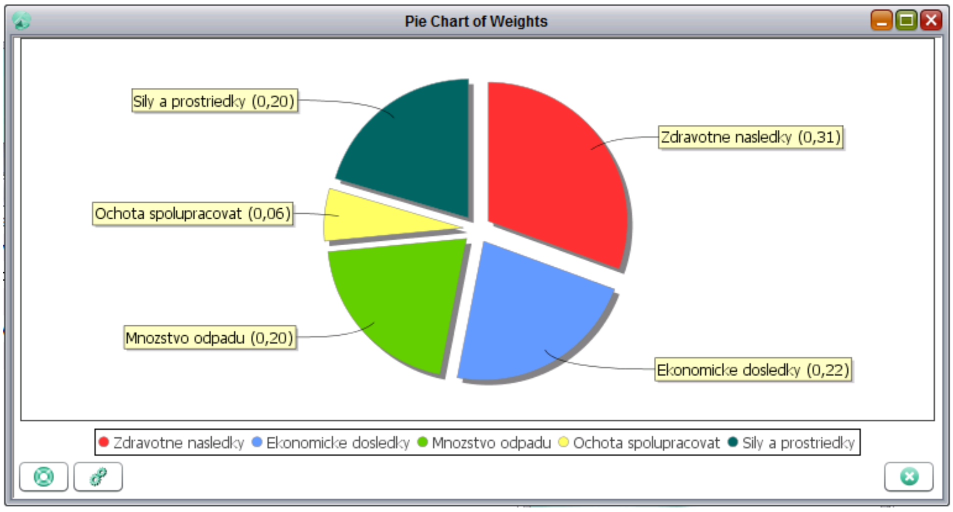


Figure 21: Weights presented as a pie chart

The presentation of outputs in a form of text report has been discussed and appreciated by participants. The report provide summary of information taken into account in strategies preferences and could be used as well as graphical outputs as supporting and transparent materials within the decision making process.

Regarding the visualization of uncertainties taken into account by the ERMIN module of the JRODOS DSS they are incorporated within the MCDA tool and one of the possible outputs accepted and appreciated by panel members is given below.

Figure 22: Uncertainties visualization

5 Conclusions and Perspectives

Stakeholder discussion panel in Slovakia has been focussed on what to do and how to proceed in presented contamination scenario and how to evaluate the potential impacts of decisions on achieving acceptable living conditions. These discussions were mindful of the inherent uncertainties associated with the real consequences of the contamination scenario, the strategies to be implemented and the potential socio-economic impacts on the affected population. Preferences collected within WP4 panel discussion served the inputs to the MCDA by WP6. The appropriate means of visualisation in terms of information for decision making when based on an MCDA tool have been discussed and evaluated.

Participants identified main areas of concern and uncertainties related to the availability of adequate personal resources of trained and prepared professionals at all levels (national, regional and local), sufficient technical resources especially related to the radiological monitoring, availability of National emergency plan with specified competences and responsibilities od stakeholders as well as reference levels and other criteria for preparation of advice, implementation and withdrawal of countermeasures. The influence of successful and sustainable preparedness process was stressed as well as advice and implementation of urgent protective measures which influence development and implementation of later countermeasures during the transition phase. The information provided to population also during the exchange of KI tablets campaign is essential.

The key criteria for selection of reconstruction strategy under the contamination scenario presented have been identified as follows: public health (health effects); costs (economical effects); personal and technical resources; wastes; population acceptance and willingness to cooperate on realisation of options of particular restoration strategies (self-help); attitude to property and home; relation to receiving society during the relocation and to certain degree indifference of people in peace time and during the emergency preparedness process; political decisions; role of state, education and professionalism; infrastructure.

The formal decision aiding tool such as multi-criteria decision making (MCDA) have been presented and tested during the stakeholder panel to see how it can be adapted and used for uncertainty handling and “robust” decision making for radiological emergency. The tool was helpful in identifying of weights of particular criteria influencing selection of restoration strategies and giving the preferences by different stakeholders. The participating stakeholders effectively used the decision aiding tool MCDA which was helpful in thorough discussions and supportive in making decisions.

APPENDIX D - Potentially overruling countermeasure features

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Potentially overruling countermeasure features in decision making based on MCDA

Lead Author: Kasper G. Andersson (DTU)

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Abstract

Multi Criteria Decision Analysis (MCDA) with stakeholder participation has been suggested as a way to reach mutually acceptable and robust decisions regarding methods and strategies for recovery of inhabited land areas and food production systems severely contaminated by an airborne radioactive plume from a severe nuclear power plant accident. However, the method would rely on a system for balancing the pros and cons of different intervention options with respect to a multitude of features that cannot directly be quantified and compared in common (e.g., monetary) units. One of the concerns is that with a system of this type assigning a relative score to each criterion and then relatively weighting each criterion with respect to importance for a desirable solution, it can be difficult to keep track of those method features that are so important for the outcome that they might alone lead to an overruling of any MCDA based decision, in which the features are only taken into account with a certain weighting. This report contains an overview of such potentially critically important or 'overruling' features for each countermeasure suggested in the European Handbooks for recovery of contaminated inhabited areas and food production systems. It is the intention that these new short descriptions of countermeasure features should be looked at after an MCDA based analysis, to check if such highly important features can in themselves be accepted in the given situation, thus minimizing the risk of introducing undesired solutions.

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1. Introduction

Nuclear and radiological accident scenarios significantly affecting large areas of land are generally highly challenging and complex to address with the objective of optimized restoration, to the extent possible, of 'normal' lifestyles (recovery). This is because each potentially applicable restoration option (countermeasure) is associated with a large number of case specific features or criteria, each with positive and/or negative effects on the implementation outcome of the countermeasure. Such criteria could for example comprise the health effect or radiological impact (e.g., change in dose reduction to the population, incremental dose to countermeasure implementers), direct costs of the implementation (e.g., worker wages, equipment, consumables, transport, treatment and storage of any waste produced, and other monetary influences), environmental impact (e.g., risk of pollution of groundwater, impact on soil fertility, risk of erosion), legal impact (conflicts between the outcome or processes of the intervention and current legislation in the area), social impact (e.g., restrictions on further use of land and amenities, loss of income, communication needs) and ethical impact (e.g., equity in countermeasure implementation, and public consent) (Nisbet et al., 2010; Nisbet et al., 2010a). Only few such criteria can, within some uncertainty bounds, reasonably be quantified in units (e.g., monetary) in a way that permits partial analysis of the relative desirability of each option in the specific case.

To facilitate the process of decision making, it has therefore been suggested by many (see, e.g., Mustajoki et al., 2007) to employ a systematic computer-based approach to examine the options, their features and the entire trade-off process involved in optimized decision making throughout facilitated interaction and discussions with stakeholders (representatives of individuals, groups or parties who are somehow affected by the decisions to be made, or in other ways have a share in them). In MCDM (multiple-criteria decision making) or MCDA (multiple-criteria decision analysis), a first step is to establish the aim for the particular scenario in question (context). Then the options that may potentially be used to reach the aim should be identified (intervention options). When this is in place the next step would be to identify criteria for assessing the consequences of the individual options. A number of examples of criteria of different kinds relevant to the decision process for recovery of radioactively contaminated areas were given above, in the first paragraph. Next comes the inevitably very tricky step described by Papamichail & French (2013) to consider the consequences of the possible impact under each criterion and on this background to score the options on the criteria. Each of these scores would often be based on a multitude of influencing factors, and not be easy to overview.

Finally, weights are assigned to each of the criteria, which is also tricky, as weights are here given to more or less general features like 'health effect', 'direct costs', 'social impact' and 'environmental impact', perhaps without the possibility of keeping it very clear in mind exactly which issues lay beneath in the specific case. Nevertheless, it is clear that under all circumstances, a decision must be taken as to which intervention options should be implemented, and at least MCDA following this type of procedure can in principle encompass evaluation of all factors deemed to be of importance. Following a series of stakeholder driven decision making workshops using the MCDA tool Web-HIPRE (available with the RODOS decision support system), Geldermann et al. (2009) concluded that MCDA was 'considered to be a suitable framework for supporting, structuring and documenting decision processes, for understanding and bringing together opinions and perspectives of all participants with diverse backgrounds and expert knowledge and for providing transparency within emergency and remediation management'. It seems here to implicitly be considered that the strength of stakeholder driven MCDA lies not only in analyzing the requirements of an effective optimization process, e.g., in training sessions, but that it is recommended to use the method in an actual accident management decision situation. This view seems to be supported by a number of authors who have analysed the MCDA process in the context of nuclear accident decision making (e.g., Turcanu et al., 2008; Mercat-Rommens et al., 2015; Perny & Vanderpooten, 1998), although Mustajoki et al. (2007) report that their decision conferencing participants found this process 'especially suitable for increasing the preparedness planning in advance and exercises, but the decision process could include elements of this approach also in a real emergency situation'.

Obviously, the entire decision process is highly sensitive to particularly the relative scores given to the options on each criterion, as well as to the weights assigned to each criterion. If for example all scores have to be given on a scale from 0 to 100, the score of a truly undesired (potentially disastrous) environmental feature of an option would result in a very low score (perhaps even 0) on this criterion (although other environmental features may also influence the overall score of the criterion). Coming to the stage of weighting the criteria, it might be that due to priority focus on, e.g., solving the health problem thoroughly and taking good care of the social impact, the environmental criterion would receive a relatively low weighting, which could mean that for example an alternative option with criteria where there were perhaps no scores lower than 10 (no potential disasters) would come out of the analysis with less total 'desirability' (lower overall weighted score).

The above was an example to highlight that although the MCDA process seemingly offers great transparency and provides a result that will be likely to be seen by the involved stakeholders as a 'best compromise' taking into account all important factors, thus facilitating consensus, there is a risk that important aspects may be hidden in the process, since the assumption that scores can unproblematically be added and weighted against each other to provide the most desirable solution will not necessarily be valid in all cases. This problem would for example not be addressed in a sensitivity analysis of the type suggested by Papamichail & French (2013).

It is therefore very important that the facilitator (or a person acting in the process as co-facilitator) has in-depth knowledge of the intervention options and their potential impacts with respect to the different criteria used in the analysis. As very deep expert knowledge on all countermeasure options will often not be available in national fora making the decisions, and to avoid that potentially truly crucial features are lost track of in the processing of criteria scores and weights it can be useful to provide an overview of such features that may at least under some conditions lead to not readily reversible severe repercussions. The purpose of this note is to pinpoint in an 'easy-overview' format features of each of the recovery options in the European Handbooks for assisting in the management of contaminated inhabited areas and food production systems in Europe following a radiological emergency, which could be perceived as particularly problematic and lead to (not easily reversible) undesired effects.

According to Raskob et al. (2018), a definition offered for the term robustness in MCDA in disaster management is: 'A robust alternative is an alternative that is simultaneously good and not too risky where good is defined by having a good performance in most cases without having a too poor performance in any single scenario', whereas others give the definition 'A robust alternative is defined as one with relatively small regret compared to the alternative across a wide range of plausible futures'. It is thus clear that information maintaining the focus on avoiding identified pitfalls that can lead to great regrets is helpful in deriving a robust solution from a series of alternatives.

It should be noted acceptability / desirability is not an easy term to define generically for different intervention options. As an example, a recovery decision-making tabletop exercise was carried out in the Nordic countries (Lauritzen, 2001) to examine and promote decision-making based on the principles of optimizing the effect of the measures, taking into account relevant criteria. The scenario was an airborne contamination of food production areas with ^{137}Cs. The background material for the assessments of the individual national groups was a series of Nordic templates containing information on the features of each of 37 countermeasures that had been published the year before (Andersson et al., 2000). All of the countermeasures were among other things evaluated with respect to relevance, practicability and acceptability, and the outcome in the different countries was very different. For example, in Denmark and Finland all ploughing and tilling procedures (including deep ploughing) were deemed to be acceptable by farmers, industry, consumers and the public in general, whereas there were great concerns about some of these in Norway and Sweden. Although an effort was made to conduct the consultations in the same way in the different countries, the differences may however to some extent reflect different facilitators' influences, for instance in pointing out potential dangers. Still, it is remarkable that out of the 37 options, there were only 4 that all countries found to be both relevant, practicable and acceptable. This also highlights the need to make an effort well in advance of any contaminating incident, to select a limited, but sufficient, number of options that it is certain can be used in an acceptable way in the country in question, so that arrangements can be made to include them in a preparedness that is operational and can be implemented within a reasonable time to maximize benefits (some highly beneficial countermeasures require very early implementation).

Finally, the reader should note that the countermeasure compilations and data descriptions in the European handbooks were developed over a period up to 2004 (Brown et al., 2005), and should soon be reviewed and updated with new methods and findings that have emerged since then. The update should comprise novel methods based on new technical advancements, methods for new surface types, and results of investigations made over the following years, including the findings from the recovery work dealing with the Fukushima accident.

2. The structure and use of the new information templates

In the following a schematic account is given of features of each management option of the European Recovery Handbooks for inhabited areas and food producing areas, which can be particularly important to keep in mind before making strategical decisions if one wants to avoid serious and in some cases irreversible problems. The intention is that these short texts could be looked at together with the overall weighted scores produced by MCDA to ensure nothing important is forgotten when the decision is taken. However, for the MCDA process itself, it is important to look at all the features described for each countermeasure in the relevant European recovery handbook. The information in the present report information is not suitable either for, e.g., countermeasure implementers, who need a much wider range of considerations, some of which are treated in the recovery handbooks. It is assumed that countermeasures are applied in reasonable agreement with the handbook recommendations.

The criteria selected for this particular purpose relate to health, direct costs, environment, legality, social and ethical concerns.

Health:

Information required for a thorough analysis of health impact is given in the European handbook templates. The health issues described in the present report address generally potentially overruling concerns, such as whether the countermeasures can be expected with the given case specific contamination level to solve the health problem satisfactorily (if the dose level is still not reduced to a level that acceptably permits human activity there is no benefit in carrying out the countermeasure). Other concerns affecting the health effect include the need for instructions for optimized countermeasure implementation. Even if the countermeasure requires only the use of a spade, the operator needs to understand the objective – otherwise the result can be an irreversible disaster.

There are for example also countermeasures for which it is crucial to keep in mind that they must be carried out over a short time period after the contamination took place, to have the desired effect. Depending on preparation work, this might not be possible in the given case.

Direct costs:

Information required for a thorough analysis of direct method implementation costs is given in the European handbook templates. Potentially overruling issues could in this case include unusually high waste management costs. The Fukushima accident has demonstrated the problems that may arise in relation to production of large amounts of waste that must be managed and stored safely. Waste management costs need to be seen as an integral part of the countermeasure implementation strategy wrt. justification/optimization. The waste management costs may greatly depend on whether the repository must comply with current legislation in general for radioactivity disposal or the rules may be changed in view of an emergency. Also loss of marketing possibilities for contaminated goods can be made up in monetary units.

Environment:

Information required to judge the full environmental implications is given in the European handbook templates. Potentially overruling issues could in this case include the environmental impact of huge waste generation, which requires storage. Where possible advice is given for minimization of waste production (not subsequent waste volume reduction, which is a separate waste handling issue). Concerns are also given to avoiding contamination spreading in the environment, where it is judged to potentially be particularly important. Where there could be serious issues with toxicity, soil fertility loss, groundwater contamination, etc. reminders are given.

Legality:

Legality aspects are described in full in the European handbook templates. It should here be noted that national legislations may differ considerably, and in particular that legislation may be subject to considerable changes in the event of a large emergency with wide-ranging consequences, as new priorities are likely to arise. At all times, there must be a focus on the general laws protecting society as well as on the property legislation. Naturally, maximum permitted food contamination levels in trade need to be respected. Decisions need to be made, e.g., as to whether food contaminant dilution is a viable way to reduce contaminant content, which should cover ethical and social concerns. Also hormonal treatments of cattle is an important legal issue. Some countermeasures may lead to restrictions on subsequent tilling of land, and these need to be controlled through legislation.

Social:

Social aspects are described in full in the European handbook templates. It should here be noted that considerations are needed to ensure continuation of vital societal functions. Some countermeasures bury the contamination deep in the soil profile, thus inaccessible to some subsequently grown plants, and greatly reducing external dose rate. However, such methods generally make it impossible to ever remove the contamination from the area, if desired at a later time. It is therefore a very important decision to make if it is acceptable to use such countermeasures. Stakeholders in different Nordic countries have been seen to have very different views on this (Lauritzen, 2001), and the views may well change if there is a real contamination situation. It needs to be realized that this is a ‘crossroad’ decision, and there will be no way back once the countermeasure is implemented. Other important social aspects comprise acceptance of highly adverse aesthetic effects, potential for market shortages of food (dependent on extent of the contamination), and possibly increased stigmatization of an affected area.

Ethical:

Ethical aspects are described in full in the European handbook templates, and there are many ethical aspects in the considerations described above under other headings. The primary more purely ethically related aspects that could be of ‘overruling’ nature include owners’ and (groups of) society’s free informed consent to implementation of the options, and the potential of some countermeasures, particularly if not handled adequately with respect to communication strategies, for loss of trust in authorities.

3. Table of templates for inhabited areas

The countermeasures considered for inhabited areas (below numbered I-XX, where XX is the number in the original inhabited areas handbook) are:

No. in handbook	**Description of countermeasure**
Recovery phase countermeasures: Buildings (Public, industrial etc.)	
12.	Demolish buildings
13.	Fire hosing
14.	High pressure hosing (walls & roofs)
15.	Mechanical abrasion of wooden walls
16.	Roof brushing
17.	Roof cleaning with pressurised hot water
18.	Roof replacement
19.	Sandblasting (walls)
20.	Tie-down (fixing contamination to the surface)
21.	Treatment of walls with ammonium nitrate
- Indoor surfaces (all buildings)	
22.	Aggressive cleaning of indoor contaminated surfaces
23.	Other cleaning methods (scrubbing, shampoo, steam cleaning etc)
24.	Removal of furniture, soft furnishings and other objects
25.	Surface removal e.g. paint, wallpaper, carpets etc
26.	Vacuum cleaning
27.	Washing
- Precious objects and personal items	
28.	Storage, shielding / covering, gentle cleaning
Recovery phase countermeasures: Roads and paved areas (and other hard outdoor surfaces)	
29.	Firehosing
30.	High pressure hosing
31.	Surface removal (road planing) and replacement
32.	Tie-down (fixing contamination to the surface)
33.	Turning paving slabs
34.	Vacuum sweeping

Recovery phase countermeasures: Soil and grassed areas	
35.	Cover grassed and soil surfaces (e.g. with asphalt)
36.	Cover with clean soil
37.	Deep ploughing
38.	Grass cutting
39.	Manual digging
40.	Plant and shrub removal
41.	Ploughing
42.	Rotovating (mechanical digging)
43.	Skim and burial ploughing
44.	Tie-down (fixing contamination to the surface)
45.	Top soil and turf removal (manual)
46.	Top soil and turf removal (mechanical)
47.	Triple digging
48.	Turf harvesting
Recovery phase countermeasures: All outside areas	
49.	Peelable coatings
50.	Snow removal
Recovery phase countermeasures: Trees and shrubs	
51.	Collection of leaves
52.	Tree & shrub pruning/removal
Recovery phase countermeasures: Specialised surfaces (particularly metals)	
53.	Application of detachable polymer paste on metal surfaces
54.	Chemical cleaning of metal surfaces
55.	Chemical cleaning of plastic and coated surfaces
56.	Cleaning of contaminated ventilation systems
57.	Electrochemical cleaning of metal surfaces
58.	Filter removal
59.	Ultrasound treatment with chemical decontamination

4. Table of templates for food production

The countermeasures considered for food production (below numbered F-XX, where XX is the number in the original food production handbook) are:

No. in handbook	Description of countermeasure
Recovery phase countermeasures: General applicability	
7.	Dilution
8.	Feeding animals w. crops/milk in excess of intervention levels
9.	Leaching of horticultural peat
10.	Prevention of fire in forests, shrubland and other sensitive areas
11.	Restriction on the entry of food into the foodchain (food ban)
12.	Selection of alternative land use
Recovery phase countermeasures: Soil/crop/grassland	
13.	Application of lime to arable soils and grassland
14.	Application of potassium fertilisers to arable soils and grassland
15.	Deep ploughing
16.	Early removal of crops
17.	Land improvement
18.	Processing of crops for subsequent consumption
19.	Pruning / defoliation of fruit trees and vines
20.	Selection of edible crop that can be processed
21.	Shallow ploughing
22.	Skim and burial ploughing
23.	Topsoil removal
Recovery phase countermeasures: Livestock and animal products	
24.	Addition of AFCF to concentrate ration
25.	Addition of calcium to concentrate ration
26.	Administration of AFCF boli to ruminants
27.	Administration of clay minerals to feed
28.	Change of hunting season
29.	Clean feeding
30.	Decontamination techniques for milk
31.	Distribution of salt licks containing AFCF

No. in handbook	Description of countermeasure
32.	Live monitoring
33.	Manipulation of slaughter times
34.	Processing of milk for human consumption
35.	Salting of meat
36.	Selective grazing regime
37.	Slaughtering of dairy livestock
38.	Suppression of lactation before slaughter
Recovery phase countermeasures: Societal	
39.	Compensation scheme
40.	Dietary advice
41.	Food labelling
42.	Local provision of monitoring equipment
43.	No active implementation of management options (do nothing)
44.	Processing and/or storage prior to consumption
45.	Raising of intervention limits
46.	Restrictions on gathering wildfoods

5. The templates

ID: I-12 - Buildings -	
Demolish buildings	
Objective	**To remove contamination associated with buildings. Demolishing buildings will reduce external gamma and beta doses in the future if the area is resettled as long as other outdoor surfaces have also be decontaminated or removed.**
Potentially large irreversible problem	
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Include potentially huge waste management costs and creation of new buildings.
Environment	If applied over a large area, this could create enormous amounts of waste. A thorough waste handling strategy is crucial.
Legality	Owners' / society's permission.
Social	People, hospitals, schools, businesses, etc., could stand without a residence – a strategy is needed to handle this in an acceptable way. Potential for high level of distress.
Ethical	Owners' / society's consent.

ID: I-13	- Buildings -
Firehosing (walls & roofs)	
Objective	**To reduce external gamma and beta doses from contamination on external walls and roofs of buildings within inhabited areas, and reduce inhalation dose from material resuspended from these surfaces.**
Potentially large irreversible problem	
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. Make sure roof gutters are cleaned thoroughly in the end. The method is considerably less effective if applied a few months after the contamination took place.
Direct costs	-
Environment	Make certain that contamination is not washed into the building
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-14	- Buildings -
High pressure hosing (walls & roofs)	
Objective	**To reduce external gamma and beta doses and inhalation doses from contamination on external walls and roofs of buildings within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. Make sure roof gutters are cleaned thoroughly in the end. The method is considerably less effective if applied a few months after the contamination took place.
Direct costs	-
Environment	Make certain that contamination is not washed into the building
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-15	- Buildings -
Mechanical abrasion of wooden walls	
Objective	**To reduce external gamma and beta doses from contamination on external wooden walls of buildings within inhabited areas, and reduce inhalation dose from material resuspended from these surfaces.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-16	- Buildings -
Roof brushing	
Objective	**To reduce external gamma and beta doses and inhalation doses from contamination on roofs of buildings within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. Make sure roof gutters are cleaned thoroughly in the end. The method is considerably less effective if applied a few months after the contamination took place.
Direct costs	-
Environment	Make certain that contamination is not washed into the building
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-17	- Buildings -
Roof cleaning with pressurised hot water	
Objective	**To reduce external gamma and beta doses and inhalation doses from contamination on roofs of buildings within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. Make sure roof gutters are cleaned thoroughly in the end. The method is considerably less effective if applied a few months after the contamination took place.
Direct costs	-
Environment	Make certain that contamination is not washed into the building
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-18	- Buildings -
Roof Replacement	
Objective	**To reduce external gamma and beta doses and inhalation doses from contamination on roofs of buildings within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Include potentially large waste management costs and new roofs.
Environment	If applied over a large area, this could create large amounts of waste. A thorough waste handling strategy is crucial.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-19	- Buildings -
Sandblasting (walls)	
Objective	**To reduce external gamma and beta doses and inhalation doses from contamination on walls of buildings within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Include potentially considerable waste management costs.
Environment	If applied over a large area, this could create large amounts of waste. A thorough waste handling strategy is crucial.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-20	- Buildings -
Tie-down (fixing contamination to the surface)	
Objective	**To reduce inhalation doses from material resuspended from external building surfaces within inhabited areas in the short or long term.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. The method is considerably less effective if applied a few weeks after the contamination took place.
Direct costs	If the fixative is of a type that needs subsequent removal, there is a (limited) waste management cost.
Environment	Fixative must be non-toxic
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-21	- Buildings -
Treatment of walls with ammonium nitrate	
Objective	**To reduce external dose from caesium contamination on external walls of buildings in inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. The method is considerably less effective if applied a few months after the contamination took place.
Direct costs	-
Environment	The waste solution can normally not be collected and will reach soil or sewers. At prescribed concentrations the ammonium nitrate solution is unlikely to lead to great changes in soil pH or groundwater pollution.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-22	- Buildings -
Aggressive cleaning of indoor contaminated surfaces	
Objective	**To reduce inhalation and external gamma and beta doses arising from contamination on indoor floor and wall surfaces of large public buildings (e.g. railway stations) within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. The method is considerably less effective if applied a few months after the contamination took place.
Direct costs	Depends on technique used. Sandblasting can generate rather much waste, which must be managed.
Environment	If applied over a large area, this could create large amounts of waste. A thorough waste handling strategy is crucial.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-23	**- Buildings -**
Other cleaning methods (scrubbing, shampoo, steam cleaning)	
Objective	**To reduce inhalation and external gamma and beta doses arising from contamination on internal surfaces of buildings and indoor objects within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. The method is considerably less effective if applied a few months after the contamination took place.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-24	**- Buildings -**
Removal of furniture, soft furnishings and other objects	
Objective	**To reduce inhalation and external gamma and beta doses arising from contamination on indoor objects, furnishings and fixtures within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Can generate much waste, which must be managed.
Environment	If applied over a large area, this could create very large amounts of waste. A thorough waste handling strategy is crucial.
Legality	Owners' / society's permission.
Social	Distress over loss of personal/public properties.
Ethical	Owners' / society's consent.

ID: I-25	- Buildings -
Surface removal (indoor)	
Objective	**To reduce inhalation and external gamma and beta doses arising from contamination on indoor surfaces of buildings (primarily floors, walls and ceilings) within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	E.g., wooden floor removal can generate rather much waste, which must be managed.
Environment	If applied over a large area, this could create large amounts of waste. A thorough waste handling strategy is crucial.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-26	- Buildings -
Vacuum cleaning (indoor)	
Objective	**To reduce inhalation and external gamma and beta doses arising from contamination on internal surfaces of buildings and indoor objects within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. The method is considerably less effective if applied a few months after the contamination took place.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-27	- Buildings -
Washing (indoor surfaces)	
Objective	**To reduce inhalation and external gamma and beta doses arising from contamination on internal surfaces of buildings and indoor objects within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. The method is considerably less effective if applied a few months after the contamination took place.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-28	- Buildings -
Storage, shielding, covering, gentle cleaning of precious objects	
Objective	**To reduce inhalation and external gamma and beta doses arising from contamination on personal and precious objects within inhabited areas. This option is likely to be implemented primarily for public reassurance as exposure from personal and precious objects is unlikely to be a significant contribution to an individual's dose.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-29	- Roads and paved areas -
Firehosing (roads & paved areas)	
Objective	**To reduce inhalation and external gamma and beta doses from contamination on roads, paved and other outdoor areas with hard surfaces within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. Make sure road sides/gutters are cleaned thoroughly in the end. The method is considerably less effective if applied a few months after the contamination took place.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-30	- Roads and paved areas -
High pressure hosing (roads & paved areas)	
Objective	**To reduce inhalation and external gamma and beta doses from contamination on roads, paved and other outdoor areas with hard surfaces within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. Make sure road sides/gutters are cleaned thoroughly in the end. The method is considerably less effective if applied a few months after the contamination took place.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-31	- Roads and paved areas -
Surface removal and replacement (roads & paved areas)	
Objective	**To reduce inhalation and external gamma and beta doses from contamination on roads, paved and other outdoor areas with hard surfaces within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Consider potentially huge waste management and resurfacing costs.
Environment	If applied over a large area, this could create enormous amounts of waste. A thorough waste handling strategy is crucial.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-32	- Roads and paved areas -
Tie-down (fixing contamination to the paved surface)	
Objective	**To prevent enhanced resuspension during implementation of options that create dust, particularly in dusty environments.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	-
Environment	Fixative must not be toxic to the environment.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-33	- Roads and paved areas -
Turning paving slabs	
Objective	**To reduce inhalation and external gamma and beta doses from contamination on roads, paved and other outdoor areas with hard surfaces within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	The option does not remove the contamination from the area. However, it does not prevent subsequent removal if desired.
Ethical	Owners' / society's consent.

ID: I-34	- Roads and paved areas -
Vacuum sweeping (roads & paved areas)	
Objective	**To reduce inhalation and external gamma and beta doses from contamination on roads, paved and other outdoor areas with hard surfaces within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-35	- Soil and grassed areas -
Cover grassed and soil surfaces (e.g. with asphalt)	
Objective	**To reduce inhalation and external gamma and beta doses from contamination in outdoor areas covered in grass or soil within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Asphalt cover will add considerable cost.
Environment	Total loss of biodiversity in the treated area. Total loss of fertility in the treated area.
Legality	Owners' / society's permission.
Social	The option does not remove the contamination from the area. It severely complicates subsequent contamination removal if desired. Adverse aesthetic effect.
Ethical	Owners' / society's consent.

ID: I-36	- Soil and grassed areas -
Cover with clean soil	
Objective	**To reduce inhalation and external gamma and beta doses from contamination in outdoor areas covered in grass or soil within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	-
Environment	Loss of biodiversity in the treated area. Loss of fertility in the treated area if the clean soil is dug up subsoil.
Legality	Owners' / society's permission. Subsequent restrictions on tilling of treated land.
Social	The option does not remove the contamination from the area. It makes it virtually impossible to ever remove the contamination if desired later. Adverse aesthetic effect
Ethical	Owners' / society's consent.

ID: I-37	- Soil and grassed areas -
	Deep ploughing
Objective	**To reduce inhalation and external gamma and beta doses from contamination in outdoor areas covered in grass or soil within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. Poor beneficial effect likely if soil is very sandy or dry. Requires thorough instructions for operator to optimize positive health effect.
Direct costs	-
Environment	Loss of biodiversity in the treated area. Loss of fertility in the treated area. Assess and consider groundwater level in advance.
Legality	Owners' / society's permission. Subsequent restrictions on tilling of treated land.
Social	The option does not remove the contamination from the area. It makes it virtually impossible to ever remove the contamination if desired later. Adverse aesthetic effect
Ethical	Owners' / society's consent.

ID: I-38	- Soil and grassed areas -
	Grass cutting & removal
Objective	**To reduce inhalation and external beta and gamma doses from contamination on outdoor grassed areas within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. Needs to be carried out as quickly as possible (within days), and before the first precipitation comes. Highly beneficial in preventing contamination of underlying soil. Needs prior planning/public information to use as self-help measure.
Direct costs	Consider potentially considerable waste management costs.
Environment	Waste management strategy must exist from the start.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-39	- Soil and grassed areas -
Manual digging	
Objective	**To reduce inhalation and external gamma and beta doses from contamination in outdoor areas covered in grass or soil within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. The digging method needs to be optimized in relation to prior assessments of the contamination profile in the soil. The method has potential as a self-help measure, but should not be carried out without thorough information / tutoring. Since the effect of the method is irreversible, it is essential to do it right.
Direct costs	Can be highly laborious and slow in large areas.
Environment	Loss of biodiversity in the treated area. Possibly loss of fertility in the treated area. Assess and consider groundwater level in advance.
Legality	Owners' / society's permission. Subsequent restrictions on tilling of treated land.
Social	The option does not remove the contamination from the area. It makes it virtually impossible to ever remove the contamination if desired later. Adverse aesthetic effect
Ethical	Owners' / society's consent.

ID: I-40	- Soil and grassed areas -
Plant and shrub removal	
Objective	**To reduce inhalation and external gamma and beta doses from contamination in outdoor areas that contain shrubs or plants within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. Highly beneficial to apply as early as possible; contaminant concentrations in the removed biomaterial are highest then.
Direct costs	Consider potentially large waste management costs.
Environment	If applied over a large area, this could create large amounts of waste. A thorough waste handling strategy is crucial. Loss of biodiversity.
Legality	Owners' / society's permission.
Social	Adverse aesthetic effect
Ethical	Owners' / society's consent.

ID: I-41	- Soil and grassed areas -
Ploughing	
Objective	**To reduce inhalation and external gamma and beta doses from contamination in outdoor areas covered in grass or soil within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. Poor beneficial effect likely if soil is very sandy or dry. Requires thorough instructions for operator to optimize positive health effect.
Direct costs	-
Environment	Loss of biodiversity in the treated area. Assess and consider groundwater level in advance.
Legality	Owners' / society's permission. Subsequent strict restrictions on tilling of treated land.
Social	The option does not remove the contamination from the area. It makes it virtually impossible to ever remove the contamination if desired later. Adverse aesthetic effect
Ethical	Owners' / society's consent.

ID: I-42	- Soil and grassed areas -
Rotovating	
Objective	**To reduce inhalation and external gamma and beta doses from contamination in outdoor areas covered in grass or soil within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. Simple soil mixing method that is not very effective.
Direct costs	-
Environment	Loss of biodiversity in the treated area. Assess and consider groundwater level in advance.
Legality	Owners' / society's permission.
Social	The option does not remove the contamination from the area. It makes it virtually impossible to ever remove the contamination if desired later. Adverse aesthetic effect
Ethical	Owners' / society's consent.

ID: I-43	- Soil and grassed areas -
Skim and burial ploughing	
Objective	**To reduce inhalation and external gamma and beta doses from contamination in outdoor areas covered in grass or soil within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. Poor beneficial effect likely if soil is very sandy or dry. Requires very thorough transfer of information to operators on how to obtain a good dose reductive effect – and supervision. Not a simple ploughing procedure.
Direct costs	Very few skim and burial ploughs exist in the world, so implementation in operational preparedness requires special plough production. This also means that it could take considerable time to start ploughing.
Environment	Loss of biodiversity in the treated area. Assess and consider groundwater level in advance.
Legality	Owners' / society's permission. Subsequent restrictions on tilling of treated land.
Social	The option does not remove the contamination from the area. It makes it virtually impossible to ever remove the contamination if desired later. Adverse aesthetic effect
Ethical	Owners' / society's consent.

ID: I-44	- Roads and paved areas -
Tie-down (fixing contamination to the soil surface)	
Objective	**To reduce inhalation doses from material resuspended from soil/grass areas within inhabited areas over a short period.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	-
Environment	Fixative must not be toxic to the environment.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-45	- Soil and grassed areas -
Top soil and turf removal (manual)	
Objective	**To reduce inhalation and external beta and gamma doses from contamination on outdoor grassed areas within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. The method has potential as a self-help measure, but should not be carried out without advise/supervision. The removal depth should be optimized in relation to measurements of the local contamination depth in the soil. Highly beneficial to apply as early as possible, when contaminant penetration into soil is less (waste minimisation).
Direct costs	Consider potentially huge waste management. Can be highly laborious and slow in large areas.
Environment	If applied over a large area, this could create enormous amounts of waste. A thorough waste handling strategy is crucial. Loss of biodiversity.
Legality	Owners' / society's permission.
Social	Adverse aesthetic effect
Ethical	Owners' / society's consent.

ID: I-46	- Soil and grassed areas -
Top soil and turf removal (mechanical)	
Objective	**To reduce inhalation and external beta and gamma doses from contamination on outdoor grassed areas within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. The removal depth should be optimized in relation to measurements of the local contamination depth in the soil. Highly beneficial to apply as early as possible, when contaminant penetration into soil is less (waste minimisation).
Direct costs	Consider potentially huge waste management.
Environment	If applied over a large area, this could create enormous amounts of waste. A thorough waste handling strategy is crucial. Loss of biodiversity.
Legality	Owners' / society's permission.
Social	Adverse aesthetic effect
Ethical	Owners' / society's consent.

ID: I-47 — Triple digging	- Soil and grassed areas -
Objective	**To reduce inhalation and external gamma and beta doses from contamination in outdoor areas covered in grass or soil within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. The digging method needs to be optimized in relation to prior assessments of the contamination profile in the soil. The method has potential as a self-help measure, but should not be carried out without thorough information / tutoring. Since the effect of the method is irreversible, it is essential to do it right.
Direct costs	Can be highly laborious and slow in large areas.
Environment	Loss of biodiversity in the treated area. Possibly loss of fertility in the treated area. Assess and consider groundwater level in advance.
Legality	Owners' / society's permission. Subsequent restrictions on tilling of treated land.
Social	The option does not remove the contamination from the area. It makes it virtually impossible to ever remove the contamination if desired later. Adverse aesthetic effect.
Ethical	Owners' / society's consent.

ID: I-48 — Turf harvesting	- Soil and grassed areas -
Objective	**To reduce inhalation and external beta and gamma doses from contamination on outdoor grassed areas within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there. The removal depth should be optimized in relation to measurements of the local contamination depth in the soil. Highly beneficial to apply as early as possible, when contaminant penetration into soil is less (waste minimisation). Only works with a mature turf layer on the soil. Not for soil with many pieces of rock (wrecks equipment).
Direct costs	Consider potentially huge waste management.
Environment	If applied over a large area, this could create enormous amounts of waste. A thorough waste handling strategy is crucial. Loss of biodiversity.
Legality	Owners' / society's permission.
Social	Adverse aesthetic effect
Ethical	Owners' / society's consent.

ID: I-49	- All outside areas -
Peelable coatings	
Objective	**To reduce inhalation and external gamma and beta doses from contamination on external walls and roofs of buildings and paved/road surfaces within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Include potentially large waste management costs.
Environment	If applied over a large area, this could create large amounts of waste. A thorough waste handling strategy is crucial. Coating material must not be toxic to the environment.
Legality	Owners' / society's permission.
Social	Adverse aesthetic effect
Ethical	Owners' / society's consent.

ID: I-50	- All outside areas -
Snow removal	
Objective	**To reduce inhalation and external gamma and beta doses from contamination on snow covered external walls and roofs of buildings and paved/road surfaces within inhabited areas.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Consider potentially huge waste management. Can be highly laborious and slow in large areas. The method has potential as a self-help measure (little instruction needed). Very beneficial before first thaw (early action), as contamination of underlying soil can thus be prevented.
Environment	If applied over a large area, this could create enormous amounts of waste. A thorough waste handling strategy is crucial.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-51	- Trees and shrubs -
Collection of leaves	
Objective	**To reduce inhalation and external gamma and beta doses from fallen leaves within inhabited areas. Mainly for use when deposition has occurred under dry conditions and when trees and shrubs are in leaf. After wet deposition, consideration should be given to decontaminating the ground under trees as most of the contamination washes straight off the trees.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Consider waste management. The method has potential as a self-help measure (little instruction needed).
Environment	If applied over a large area, this could create significant amounts of waste. A thorough waste handling strategy is crucial.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-52	- Trees and shrubs -
Tree & shrub pruning/removal	
Objective	**To reduce inhalation and external gamma and beta doses from contamination on trees and shrubs within inhabited areas. Mainly for use when deposition has occurred under dry conditions and when trees and shrubs are in leaf. After wet deposition, consideration should be given to decontaminating the ground under trees as most of the contamination washes straight off the trees.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Include potentially huge waste management costs.
Environment	If applied over a large area, this could create huge amounts of waste. A thorough waste handling strategy is crucial. Loss of biodiversity.
Legality	Owners' / society's permission.
Social	Adverse aesthetic effect
Ethical	Owners' / society's consent.

ID: I-53	- Specialised surfaces -
Application of detachable polymer paste on metal surfaces	
Objective	**To reduce external doses arising from contamination on metal surfaces in industrial buildings.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-54	- Specialised surfaces -
Chemical cleaning of metal surfaces	
Objective	**To reduce external doses arising from contamination on metal surfaces in industrial buildings.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Consider waste management costs.
Environment	If applied over a large area, this could create significant amounts of (mostly liquid) waste. A thorough waste handling strategy is crucial. Liquid recycling can largely eliminate waste problem.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-55	- Specialised surfaces -
Chemical cleaning of plastic and coated surfaces	
Objective	**To reduce external doses arising from contamination on plastic and coated surfaces in industrial buildings.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Consider waste management costs.
Environment	If applied over a large area, this could create significant amounts of (mostly liquid) waste. A thorough waste handling strategy is crucial. Liquid recycling can largely eliminate waste problem.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-56	- Specialised surfaces -
Cleaning of contaminated (industrial) ventilation systems	
Objective	**To reduce external doses arising from contamination in ventilation systems in industrial buildings.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Consider waste management costs.
Environment	If applied over a large area, this could create significant amounts of (mostly liquid) waste. A thorough waste handling strategy is crucial. Liquid recycling can largely eliminate waste problem.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-57	- Specialised surfaces -
Electrochemical cleaning of metal surfaces	
Objective	**To reduce external doses arising from contamination on metal surfaces, particularly machinery and tools in industrial buildings**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	Consider waste management costs.
Environment	If applied at large scale, this could create significant amounts of (mostly liquid) waste. A thorough waste handling strategy is crucial. Liquid recycling can largely eliminate waste problem.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: I-58	- Specialised surfaces -
Filter removal	
Objective	**To reduce external doses arising from contamination in filter systems in industrial buildings and commercial vehicles.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: 59	- Specialised surfaces -
Ultrasound treatment with chemical decontamination	
Objective	**Clean metal handtools and objects. Reassurance of the industry workforce.**
Health	First assess that the overall health risk in the area can be brought to a level that permits people to stay there.
Direct costs	-
Environment	-
Legality	Owners' permission.
Social	-
Ethical	Owners' consent.

ID: F-7	- General use -
Dilution	
Objective	**To provide foodstuffs with activity concentrations less than the intervention level.**
Health	First assess that the activity can be brought to an acceptable level.
Direct costs	-
Environment	-
Legality	Contaminated foodstuff is not normally allowed to be added to an acceptable batch to allow it to be distributed. Keep in line with Maximum Permitted Levels in trade.
Social	-
Ethical	The practice could be perceived as actively causing contamination of previously non-contaminated foodstuffs. Owners' / society's consent.

ID: F-8	- General use -
Feeding of animals with crops/milk in excess of intervention levels	
Objective	**To minimise volumes of contaminated crops (including fruits) and milk requiring disposal.**
Health	Careful planning needed to reach an acceptable level in animal food products. The activity concentration in the potential feeds should be measured and a prediction of the likely activity concentration in animal derived foodstuffs made. Not recommended for e.g. $^{134/137}$Cs contamination.
Direct costs	-
Environment	-
Legality	Keep in line with Maximum Permitted Levels in trade.
Social	-
Ethical	Owners' / society's consent.

ID: F-9	- General use -
Leaching of horticultural peat	
Objective	**Removal of (soluble) radionuclides from horticultural peat prior to its use as growing medium for greenhouse crops thereby reducing radionuclide concentration in subsequent crops.**
Health	Careful assessment of the health implications of use at the given resultant contamination level.
Direct costs	-
Environment	-
Legality	Keep in line with Maximum Permitted Levels in food for trade.
Social	Potential marketing problem, particularly for use in previously uncontaminated areas, and potential resistance of food consumers to accept crops grown in treated pea.
Ethical	Owners' / society's consent.

ID: F-10	- General use -
Prevention of fire in forests, shrubland and other sensitive areas	
Objective	**To prevent fires, and their subsequent spread so that there is less risk of radionuclide resuspension and subsequent transfer to areas used for agricultural production.**
Health	Requires ongoing programme of radiation monitoring to determine duration of restrictions
Direct costs	Consider waste management costs/strategy in advance.
Environment	If applied at large scale, this could create huge amounts of waste. A thorough waste handling strategy is crucial.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-11	- General use -
Restriction on the entry of food into the foodchain (food ban)	
Objective	**To remove food that is contaminated above the Council Food Intervention Limits (CFILs) from the foodchain.**
Health	Requires supply of less contaminated food alternative.
Direct costs	Consider waste management costs/strategy in advance.
Environment	If applied at large scale, this could create huge amounts of waste. A thorough waste handling strategy is crucial.
Legality	Owners' / society's permission.
Social	Negative consequences for farming communities. Stigma associated with areas where the management option has been applied.
Ethical	Owners' / society's consent.

ID: F-12	- General use -
Selection of alternative land use	
Objective	**To select crops or animals for the production of non-edible products.**
Health	Make certain that the new use complies with health objectives.
Direct costs	Consider waste management costs/strategy in advance. Markets may be limited for alternative crop/animal products – needs prior assessment.
Environment	The agricultural limitations of the affected land will determine the crops and practices that the land can support.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-13	- Soils/crops/grassland -
Application of lime to arable soils and grassland	
Objective	**To reduce plant uptake of some radionuclides by addition of lime to the soil.**
Health	Check that method works for radionuclides in question.
Direct costs	-
Environment	Application can change nutrient status and thus plant and animal diversity – possible changes in landscape.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-14	- Soils/crops/grassland -
Application of potassium fertilisers to arable soils and grassland	
Objective	**To reduce plant uptake of radiocaesium by addition of potassium fertilisers to the soil.**
Health	Check that method works for radionuclides in question: only radiocaesium contaminants.
Direct costs	-
Environment	Application can change nutrient status and thus plant and animal diversity – possible changes in landscape although minimal likely impact on intensively managed arable soil.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-15	- Soils/crops/grassland -
Deep ploughing	
Objective	**To reduce radionuclide uptake by crops, including pasture.**
Health	Poor beneficial effect likely if soil is very sandy or dry. Requires thorough instructions for operator to optimize positive health effect.
Direct costs	-
Environment	Loss of biodiversity in the treated area. Loss of fertility in the treated area. Assess and consider groundwater level in advance. Field drainage systems can be destroyed.
Legality	Owners' / society's permission. Subsequent restrictions on tilling of treated land.
Social	The option does not remove the contamination from the area. It makes it virtually impossible to ever remove the contamination if desired later.
Ethical	Owners' / society's consent.

ID: F-16	- Soils/crops/grassland -
Early removal of crops	
Objective	**To reduce contamination of arable land and its products.**
Health	Needs to be carried out as quickly as possible (within days), and before the first precipitation comes. Highly beneficial in preventing contamination of underlying soil. Needs prior planning/public information, e.g., to use as self-help measure.
Direct costs	-
Environment	Waste management strategy must exist from the start.
Legality	Owners' / society's permission.
Social	Disruption to the supply of crops to food industry and possible market shortages.
Ethical	Owners' / society's consent.

ID: F-17	- Soils/crops/grassland -
Land improvement	
Objective	**To reduce activity concentrations of radionuclides in animals grazing unimproved pasture.**
Health	Check that method works for the radionuclides in question.
Direct costs	-
Environment	Application can change nutrient status and thus plant and animal diversity – possible changes in landscape although minimal likely impact on intensively managed arable soil. Contamination may be moved closer to the water table possibly resulting in enhanced contamination of ground water.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-18	- Soils/crops/grassland -
Processing of crops for subsequent consumption	
Objective	**To process contaminated crops to produce final food products with activity concentrations less than intervention limits.**
Health	Check that the exact selected method works adequately for radionuclides in question.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	Disruption/adjustment of farming and related industrial activities, i.e. the supply of crops to food industry and potential for market shortages.
Ethical	Owners' / society's consent.

ID: F-19	- Soils/crops/grassland -
Pruning/defoliation of fruit trees and vines	
Objective	**To prevent, or reduce, the translocation of radionuclides from shoots and leaves to fruit of perennial plants.**
Health	Needs to be carried out as early as possible to be effective (within weeks, and, to prevent wash-off to soil, ideally before the first rainfall).
Direct costs	Consider potentially large waste management costs.
Environment	If applied over a large area, this could create large amounts of waste. A thorough waste (chemical / radioactive) handling strategy is crucial.
Legality	Owners' / society's permission.
Social	Stigma associated with areas and perceived contamination of products where the management option has been applied.
Ethical	Owners' / society's consent.

ID: F-20	- Soils/crops/grassland -
Selection of edible crop that can be processed	
Objective	**To select crops suitable for processing such that the final edible product has activity concentrations less than intervention levels.**
Health	Make certain that the new crop use complies with health objectives.
Direct costs	Is there a market for the new crops?
Environment	-
Legality	Owners' / society's permission.
Social	Stigmatisation of food products from the contaminated area may persist.
Ethical	Owners' / society's consent.

ID: F-21	- Soils/crops/grassland -
Shallow ploughing	
Objective	**To reduce radionuclide uptake by crops, including pasture.**
Health	Limited beneficial effect likely if soil is very sandy or dry. Requires thorough instructions for operator to optimize positive health effect.
Direct costs	-
Environment	Loss of biodiversity in the treated area. Adverse effect of fertility in shallow arable soil areas. Assess and consider groundwater level in advance. Field drainage systems can be destroyed.
Legality	Owners' / society's permission. Subsequent restrictions on tilling of treated land.
Social	The option does not remove the contamination from the area. It makes it virtually impossible to ever remove the contamination if desired later.
Ethical	Owners' / society's consent.

ID: F-22	- Soils/crops/grassland -
	Skim and burial ploughing
Objective	**To reduce radionuclide uptake by crops, including pasture.**
Health	Limited beneficial effect likely if soil is very sandy or dry. Requires very thorough transfer of information to operators on how to obtain a good dose reductive effect – and supervision. Not a simple ploughing procedure.
Direct costs	Very few skim and burial ploughs exist in the world, so implementation in operational preparedness requires special plough production. This also means that it could take considerable time to start ploughing.
Environment	Assess and consider groundwater level in advance.
Legality	Owners' / society's permission. Subsequent restrictions on tilling of treated land.
Social	The option does not remove the contamination from the area. It makes it virtually impossible to ever remove the contamination if desired later.
Ethical	Owners' / society's consent.

ID: F-23	- Soil and grassed areas -
	Topsoil removal
Objective	**To reduce inhalation and external beta and gamma doses from contamination on outdoor grassed areas within inhabited areas.**
Health	The removal depth should be optimized in relation to measurements of the local contamination depth in the soil. Highly beneficial to apply as early as possible, when contaminant penetration into soil is less (waste minimisation).
Direct costs	Include potentially huge waste management. Impracticable from a very large agricultural area.
Environment	If applied over a large area, this could create enormous amounts of waste. A thorough waste handling strategy is crucial. In shallow fertile layer soils this could adversely affect soil fertility. Loss of biodiversity.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-24	- Livestock and animal products -
Addition of AFCF to concentrate ration	
Objective	**To reduce activity concentrations of radiocaesium in meat or milk to below intervention levels.**
Health	Note that the method is specifically for $^{134/137}Cs$
Direct costs	The sale of milk and meat intended for human consumption is subject to Council Food Intervention Limits (CFILs). Check that these can realistically be reached.
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-25	- Livestock and animal products -
Addition of calcium to concentrate ration	
Objective	**To reduce the activity concentration of radiostrontium in milk to below intervention levels.**
Health	Note that the method is specifically for strontium contamination.
Direct costs	The sale of milk intended for human consumption is subject to Council Food Intervention Limits (CFILs). Check that these can realistically be reached.
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-26	- Livestock and animal products -
Administration of AFCF boli to ruminants	
Objective	**To reduce activity concentrations of radiocaesium in meat or milk to below intervention levels.**
Health	Note that the method is specifically for $^{134/137}$Cs
Direct costs	The sale of milk and meat intended for human consumption is subject to Council Food Intervention Limits (CFILs). Check that these can realistically be reached.
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-27	- Livestock and animal products -
Administration of clay minerals to feed	
Objective	**To reduce activity concentrations of radiocaesium in meat or milk to below intervention levels.**
Health	Note that the method is specifically for $^{134/137}$Cs
Direct costs	The sale of milk and meat intended for human consumption is subject to Council Food Intervention Limits (CFILs). Check that these can realistically be reached.
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-28	- Livestock and animal products -
Change of hunting season	
Objective	**To reduce internal dose to consumers by changing/restricting the hunting season to a period when the contamination levels in game meat are low.**
Health	Assess that the decrease in game meat contaminant concentration is likely to be sufficient for the meat to be applied/sold (CFILs).
Direct costs	-
Environment	Avoid hunting during breeding season.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-29	- Livestock and animal products -
Clean feeding	
Objective	**To reduce activity concentrations of radionuclides in milk and meat to below intervention levels.**
Health	-
Direct costs	The sale of milk and meat intended for human consumption is subject to Council Food Intervention Limits (CFILs). Check that these can realistically be reached.
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-30	- Livestock and animal products -
Decontamination techniques for milk	
Objective	**To remove contamination from milk and return this milk to the foodchain.**
Health	Method proposed only for radiocaesium and radiostrontium contamination problems.
Direct costs	The sale of milk and meat intended for human consumption is subject to Council Food Intervention Limits (CFILs). Check that these can realistically be reached.
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-31	- Livestock and animal products -
Distribution of saltlicks containing AFCF	
Objective	**To reduce activity concentrations of radiocaesium in meat or milk of free-grazing animals to below intervention levels.**
Health	Note that the method is specifically for $^{134/137}Cs$
Direct costs	The sale of milk and meat intended for human consumption is subject to Council Food Intervention Limits (CFILs). Check that these can realistically be reached.
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-32	- Livestock and animal products -
Live monitoring	
Objective	**To determine whether activity concentration in animals are below the intervention limits and/or optimisation of other management option techniques.**
Health	Very difficult if a significant part of the problem is from radionuclides that do not emit gamma radiation.
Direct costs	-
Environment	-
Legality	Owners' / society's permission.
Social	Stigma associated to affected area, when live monitoring is deemed appropriate/needed.
Ethical	Owners' / society's consent.

ID: F-33	- Livestock and animal products -
Manipulation of slaughter time	
Objective	**To determine whether activity concentration in animals are below the intervention limits and/or optimisation of other management option techniques.**
Health	-
Direct costs	The sale of meat products intended for human consumption is subject to Council Food Intervention Limits (CFILs). Check that these can realistically be reached.
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-34	- Livestock and animal products -
Processing of milk for human consumption	
Objective	**To produce milk products with activity concentrations less than intervention levels from contaminated liquid milk that would be suitable for human consumption with or without a period of storage.**
Health	-
Direct costs	The sale of milk products intended for human consumption is subject to Council Food Intervention Limits (CFILs). Check that these can realistically be reached.
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-35	- Livestock and animal products -
Salting of meat	
Objective	**To produce meat products with activity concentrations less than intervention levels from contaminated raw meat.**
Health	Only known to be effective for radiocaesium and strontium contamination.
Direct costs	The sale of meat products intended for human consumption is subject to Council Food Intervention Limits (CFILs). Check that these can realistically be reached.
Environment	Liquid waste production may not be trivial. Management must be considered.
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-36	- Livestock and animal products -
Selective grazing regime	
Objective	**To reduce activity concentrations of radionuclides in meat and milk to below intervention levels.**
Health	-
Direct costs	The sale of milk and meat products intended for human consumption is subject to Council Food Intervention Limits (CFILs). Check that these can realistically be reached.
Environment	-
Legality	Owners' / society's permission.
Social	-
Ethical	Owners' / society's consent.

ID: F-37	- Livestock and animal products -
Slaughtering of dairy livestock	
Objective	**To remove the source of contaminated milk (i.e. dairy animals) from the foodchain.**
Health	-
Direct costs	Condemned livestock carcasses. Consider waste management strategy in advance.
Environment	-
Legality	Owners' / society's permission.
Social	Lack of dairy produce unless it can be supplied from elsewhere. Stigma associated with the area affected.
Ethical	Owners' / society's consent.

ID: F-38	- Livestock and animal products -
Suppression of lactation before slaughter	
Objective	**To reduce the volume of milk requiring disposal before dairy animals are slaughtered.**
Health	-
Direct costs	-
Environment	Milk contaminated with radionuclides will be produced until milk production ceases. Milk waste management must be considered in advance.
Legality	Owners' / society's permission. Hormonal treatments using synthetic oestrogens are not permitted for food producing animals in the EU. However, if a decision has been made to slaughter dairy livestock, hormonal treatments may be used to reduce the volumes of waste milk arising before slaughter.
Social	Lack of dairy produce unless it can be supplied from elsewhere. Stigma associated with the area affected.
Ethical	Owners' / society's consent.

ID: F-39	- Societal -
Compensation scheme	
Objective	**Provision of financial support for persons affected either by radiation exposures or by social and economic side effects of management options**
Health	-
Direct costs	Depend greatly on criteria.
Environment	-
Legality	-
Social	Can lead to perception of self as "victim". Stigma associated with the area affected.
Ethical	Compensation could be seen as 'bribery' (e.g. workers paid to stay in contaminated regions).

ID: F-40	- Societal -
Dietary advice	
Objective	**Dose reduction by giving people advice on how to reduce their radionuclide intake.**
Health	-
Direct costs	-
Environment	-
Legality	-
Social	Stigma associated with the area affected.
Ethical	-

ID: F-41	- Societal -
Food labelling	
Objective	**Dose reduction by giving people advice on how to reduce their radionuclide intake.**
Health	-
Direct costs	-
Environment	-
Legality	-
Social	Dissemination of information about the management option, its rationale and possible alternatives i.e. explanation of the risks associated with differing levels of contamination, uncertainty and variance of levels. Stigma associated with the area affected.
Ethical	-

ID: F-42	- Societal -
Local provision of monitoring equipment	
Objective	**To provide the public with personal access to equipment or facilities giving information on radiation levels in foodstuffs or surroundings. Screening of home-grown or self-gathered foodstuffs for radioactivity content. Identifying areas of significant contamination in and around homes and places of work.**
Health	-
Direct costs	-
Environment	-
Legality	-
Social	Dissemination of information about the management option, its rationale and possible alternatives. Consultancy /surveillance to assess that the equipment is used right, and does not lead to wrong conclusions / increased undue anxiety. Stigma associated with the area affected.
Ethical	-

ID: F-43	- Societal -
No active implementation of management options (do nothing)	
Objective	**The minimisation or avoidance of social and economic costs of management option implementation.**
Health	Make certain that the overall health risk in the area is acceptable if nothing is done. An other scenario where ‘do nothing’ may be selected is if the risk in the area would remain too high for human activity even after implementation of any countermeasures.
Direct costs	-
Environment	-
Legality	-
Social	There may be a demand for “something to be done” or for some form of compensation. Stigma associated with the area affected if the contamination is not trivial.
Ethical	Loss of trust in authorities, particularly if the decision was subsequently overturned.

ID: F-44	- Societal -
Processing and/or storage prior to consumption	
Objective	**To process and/or store foodstuffs until the activity concentrations have declined to what is considered to be acceptable levels.**
Health	-
Direct costs	The supply and sale of commercially produced foods intended for human consumption is subject to Council Food Intervention Levels (CFILs). Check that these can realistically be reached. Whether these apply to domestically produced food or foods from the wild will depend on national legislation.
Environment	-
Legality	Owners' / society's permission.
Social	Foodstuffs that may have been radioactively contaminated may not be acceptable, when foodstuffs can be obtained from other sources.
Ethical	Owners' / society's consent.

ID: F-45	- Societal -
Raising of intervention limits	
Objective	**Raising intervention limits to allow sale or use of foodstuffs.**
Health	-
Direct costs	-
Environment	-
Legality	Society's permission: Permitted levels in foodstuffs, especially for international markets. Note that CFIL values would be in force for at most 3 months after an accident. They would subsequently have to be re-agreed by Member States or they could be adjusted to the particular accidental situation.
Social	Public confidence may decrease as consumers may lose trust in food products, and in authorities' recommendations. Requires careful communication strategy.
Ethical	Society's consent.

ID: F-46	- Societal -
Restrictions on gathering wildfoods	
Objective	**Dose reduction by reducing consumption of contaminated wild food.**
Health	-
Direct costs	-
Environment	-
Legality	Society's permission.
Social	Replacement foods may be required.
Ethical	Society's consent.

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APPENDIX E - MINUTES FROM THE DUTCH NATIONAL PANEL

Minutes of meeting

Activity Type	WP4	**Document No.**	
Subject	Minutes of the 2nd Dutch national panel meeting		
Location	RIVM, Bilthoven, The Netherlands		
Start Date	26 november 2018	**End date**	26 november 2018
Recorder of Minutes	Esther van Asselt (RIKILT), Chris Twenhöfel (RIVM)		
Document Status	Final	**Date of Preparation**	5 december 2018
List of Attendees	Erica Fritse	Ministry I&W/DCC	
	Johan Polder	RIVM	
	Chris Twenhöfel	RIVM	
	Jan de Vries	Safety Region Twente	
	Michiel Hoorweg	Ministry VWS	
	Peter van Beek	Safety Region Zeeland	
	Tom van Galen	ANVS	
	Frans Greven	GGD Groningen	
	Arnout Fischer	Wageningen University	
	Marleen Kraaij	RIVM	
	Ronald Smetsers	RIVM	
	Esther van Asselt	RIKILT	

SUMMARY OF THE KEY DISCUSSION ISSUES

Opening

Johan Polder opens the meeting. Participants introduce themselves.

Presentations on MCDA and the case study

Esther van Asselt introduces the 2nd Dutch workshop. The workshop is organised in the context of the EU-project Confidence (https://portal.iket.kit.edu/CONFIDENCE/). The concept of a Multi Criteria Decision Analysis (MCDA) is presented.

Chris Twenhöfel introduces the case study. The objective is to find an optimized recovery strategy for the city of Emmeloord in the Noordoostpolder. Five strategies with different recovery options, based on the EU project HARMONE, were presented to the panel. Recovery options aimed at the cleanup of small areas of grass, soil and plants, the interior and roofs. Three of the five cleanup strategies can be combined with a two month relocation period, increasing the number of strategies to eight. Note that the HARMONE project was not specifically targeted towards the situation in The Netherlands, i.e. dose contributions in a typical Dutch living environment may therefore deviate from those assumed in the case study.

Defining criteria for use in the MCDA

We discussed relevant criteria for use in an MCDA in ***two groups***.

Group 1 indicated that the overall goal of the recovery is the functioning of society. After discussion, the following criteria were selected:

- Health:
  - Somatic and psychic (DALY's?)
- Public support
  - Trust/self-confidence
  - Acceptance
- Costs
  - Cleanup
  - Health treatments
  - Waste disposal and storage
  - Relocation
  - Psychosocial interventions
- Feasibility
  - Technical/logistics
  - Worker capacity
  - Enforcement
- Preventing social unrest

It was noted that the psychosocial interventions will exceed the somatic cases. The case study does not take these psychosocial interventions into account.

Group 2 indicated the following criteria:

- Feasibility
  - Amount of waste
- Public acceptance
- Health
  - Avoided dose
  - Reducing psychosocial load
  - Attribution
  - Need for a health investigation
- Costs
  - Short term: costs for cleanup, treatments
  - Long term
- Quality of life
  - Quality of living environment

- Administrative
    - Communication
    - International
    - Integrity

Plenary discussion and composing a joint attribute list for use in the MCDA

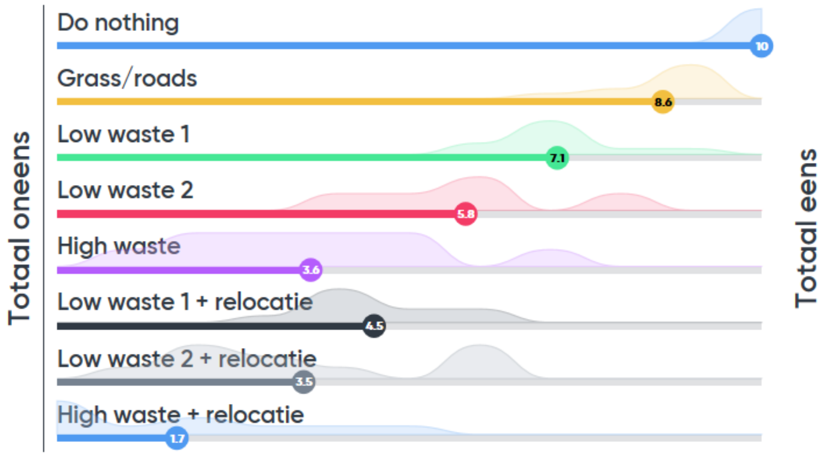
Criteria were discussed and a final list of criteria/attributes for use in the MCDA-tool was decided on:

- Health
    - Avoided dose
    - Psychosocial consequences
- Public support
    - Confidence in the strategy (honesty, competence, value....)
    - Inconvenience
    - Benifits
    - Justice
    - Transparancy
- Feasibility
    - Technical
    - Logistics
    - Lead time
    - Worker availability
- Costs (expenses and benefits)
    - Countermeasures
    - Avoided health costs
    - Infrastructure
- Administrative dilemmas:
    - Review of legal framework / International guidelines
    - (Inter)national image
    - Administrative complexity
    - Possibility for customization versus coercion
    - Preventing unrest
    - Communication strategy
- Quality of life
    - See Healthy Urban Living (healthy urban living, https://www.rivm.nl) for criteria

Demonstration of the MCDA tool

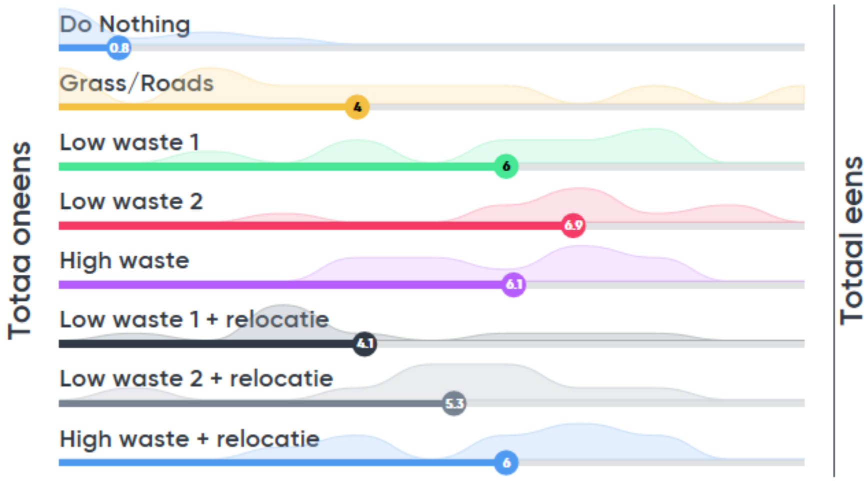
Chris Twenhöfel demonstrates the MCDA-software tool developed by KIT, Karlsruhe. Attributes for Costs and Health were predefined and implemented in the MCDA for all eight cleanup strategies. The cost attribute consisted of the costs for health treatment, relocation, cleanup, waste disposal and storage for 50 years. The health attribute consisted of the number of avoided fatal cancers over a period of 50 years after the accident. Psychosocial interventions should also be included in health and costs. It was concluded that a separate study is needed to include these in the attribute table. The use of DALY's is likely required to be able to compare these value attribute to health. The remaining criteria (public support, feasibility, administrative dilemmas, quality of life) are ranked individually by the group members via www.mentimeter.nl into a score from 0 to 10. Results are given below:

Feasibility
Proposition: “This cleanup strategy is easily feasible”



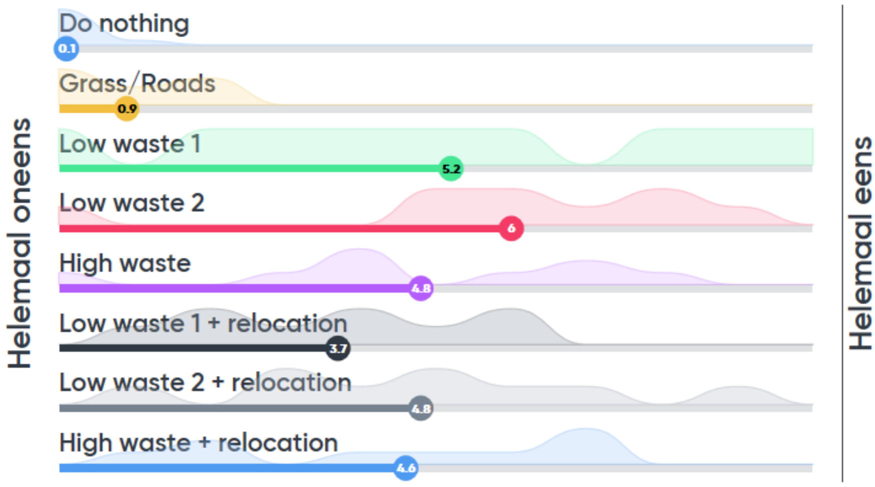
Note: the initial ranking was redone because the scores and cleanup options were unclear to the panel. The above figure shows the results of the 2nd ranking. “Totaal eens” means “totally agree”, “Totaal oneens” means “totally disagree”.

Support
Proposition: “This strategy is supported well by the population of Emmeloord”



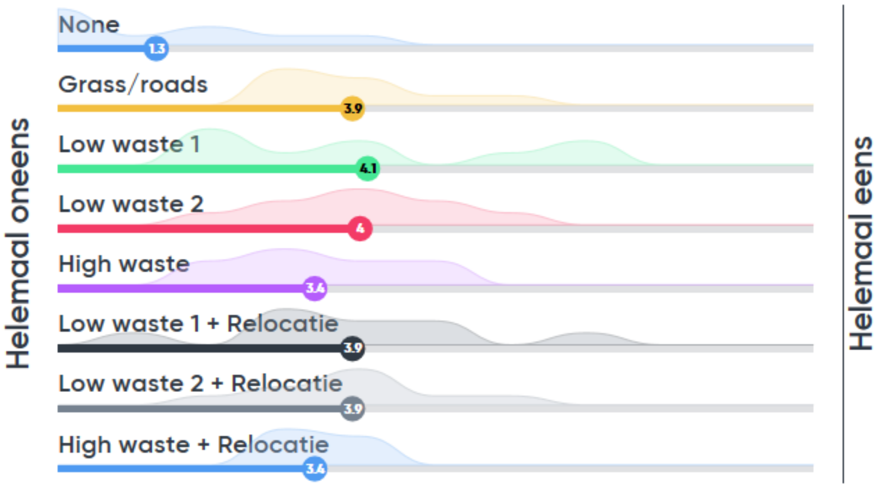
It is important that the exact consequences of the cleanup and details of who is cleaning the interior houses are known beforehand. Especially in case of relocation, people may be in and outside the houses for cleanup work. Many may not like to idea of strangers working in the house during their absence.

Administrative dilemmas
Proposition: “With this strategy I perform well as an administrator.”



Here, relocation was found difficult “to sell”. Good reasons are needed to relocate 46,000 people.

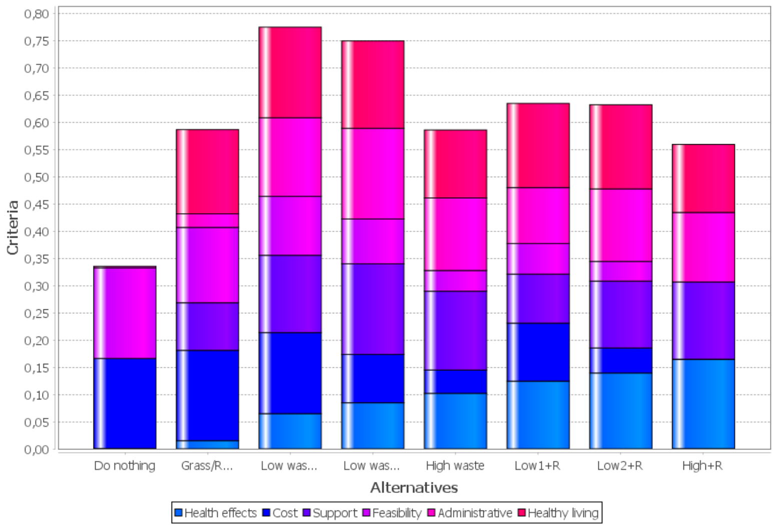
<u>Quality of life</u>
Proposition: “This strategy contributes well to the quality of life”



The panel members found it difficult to rank this criterion. None of the options obtained a high ranking.

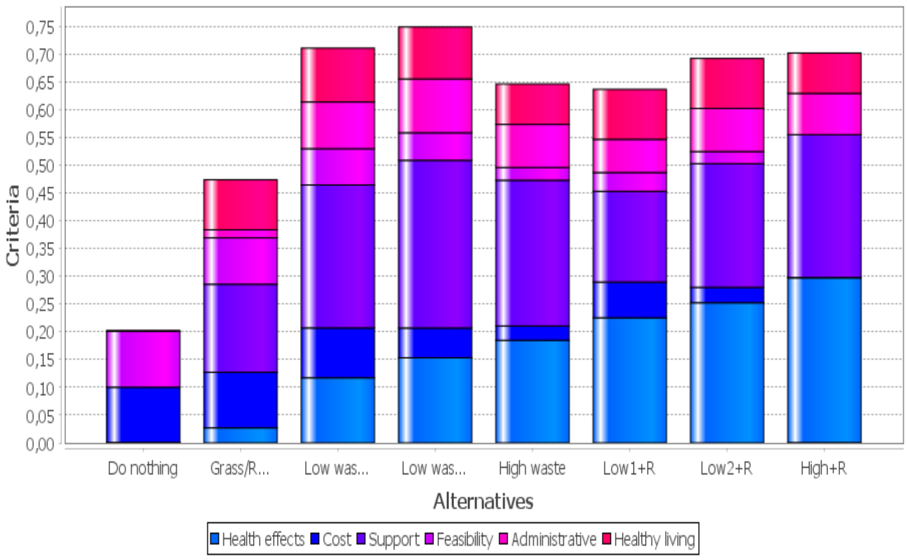
Weighting the criteria

The above attributes were entered into the MCDA tool. If all criteria are weighted equally the two low waste scenarios rank best. Results change when the individual criteria are weighted differently. The “do nothing” and the “grass/road only” scenarios always score low.



Ranking of the cleanup strategies using equal weights for all criteria.

The panel judged health and public acceptance as most important criteria in the MCDA. It was noted that in reality, the decision makers should select the relative weighting in the MCDA.



Ranking of the cleanup strategy with a threefold multiplication of the relative weight of health and public acceptance. The two waste strategies still outrank all others, but the low and high waste with relocation scenarios become 2nd best.

Plenary discussion on the results and application of the MCDA.

The quantification of psychosocial aspects are not included in the proposed attribute of the cleanup strategies. One could include, for example, a health screening or a social program after relocation as a countermeasure in the strategy.

On the application of the MCDA tool, the panel concluded:

- The MCDA tool is useful to differentiate between feasible and unfeasible cleanup strategies. This may shorten the list of strategies as well as the discussions.
- The tool contributes to transparent decision making.

- A two-step process was proposed: cleanup strategies that do not fulfill some minimum requirement (e.g. first year dose above 20 mSv) are excluded from the MCDA. Only feasible strategies are included.
- The tool is useful in structuring the discussion.
- The exact meaning of the criteria should be known beforehand. What is meant by, e.g. an administrative dilemma. One could also quantify some criteria in advance. In the preparation phase, one could consult the population via representative surveys in stakeholder panels to gain insight in criteria like public support.
- The tool helps to perceive sensitivities in the discussion (e.g. costs versus health)
- The tool could be used in exercises
- The tool could also be useful in a preparatory decision making context. It shows that multiple attributes are taken into account.

Points of special interest:

- The tool must not be viewed as the truth. It is a decision making tool, which helps the discussion. Results of the tool should always be discussed with stakeholders.
- Politics are important in decision-making. Politicians can choose a different strategy than the optimised solution from the MCDA.
- To what extent can the results of the MCDA be made public?
- The input of the population in the MCDA is important.
- How can the optimization using the MCDA tool remain manageable? In our case study, only 8 cleanup strategies and 6 criteria were included. This proved to be complex. For decision makers, the tool could be too limited to fully scope the problem.

The tool seems useful to support decision-making. The tool should be tested in different case studies, e.g. agricultural versus urban, small versus big city, et cetera.

The tool is scalable to a contamination covering the whole of the Netherlands. One could define different areas with different contamination levels and cleanup options into the cleanup strategies.

It is important to indicate where and for whom this tool is suitable.

APPENDIX F - CONFIDENCE DISSEMINATION WORKSHOP

The CONFIDENCE Dissemination workshop: Scenario based facilitated discussion on decision making under uncertainties

The CONFIDENCE Dissemination workshop “Coping with uncertainties for improved modelling and decision making in nuclear emergencies”, organized by VUJE AS, was held at Lindner Hotel, Bratislava, Slovak Republic in December, 02-05, 2019. About 90 scientists and decision makers attended the workshop.

The dissemination workshop allowed to present the results of the CONFIDENCE project, demonstrated the applicability of the developed methods and tools in interactive discussion sessions and collected feedback from the participants and end users on the work performed.

The achievements made have been presented not only in a form of presentations and posters but also via interactive workshops when all participants are involved in group work.

The unique scenario was developed which was used by each particular work package and went through the whole workshop demonstration and interactive work and discussions.

The scenario used was based on a large fictive nuclear accident at the Borsselle power plant in the Netherlands. Belgium was also affected by the plume. Wide areas had been evacuated.

In particular, the task of MCDA scenario based facilitated discussion which took place on December 4, 2019, focused on the urban decontamination of the municipality Cromstrijen/Numansdorp. Ensemble calculations of weather and source terms were used to provide frequency maps. ERMIN was used to process the scenario to provide value estimates for potentially used criteria like amount of waste, and residual dose estimations.

5 different countermeasure strategies have been discussed:

1) no actions, only monitoring,

2) low waste strategy,

3) high waste strategy,

4) low waste + relocation and

5) high waste + relocation.

The strategy developments itself as well as main concerns when facing the recovery strategy, objectives to pursue in the recovery strategy, main factors and key criteria for the strategy selection and main uncertainties affecting the decision about recovery strategy have been discussed by all participants in groups. Each group filled the questionnaire which have been collected and analysed for the purpose of the MCDA scenario based facilitated discussion.

SUMMARY
URBAN

CONFIDENCE Final Dissemination Workshop

Block 4: Stakeholders involvement in Strategy development in the transition phase

ENVIRONMENT (URBAN or AGRICULTURAL?)....URBAN....

Questions for discussion

(To be completed by each discussion group)

Q1. Which are the main concerns when facing the recovery strategy?

- 2 ☐ Feasibility 1 1
- 3 ☐ Health impacts, 1 1 1
- 1 ☐ Environmental consequences, 1
- Most frequent → 4 ☐ Social impacts, 1 1 1 1
- 1 ☐ Economic aspects, 1
- ☐ Other issues: Which?......................

Q 2. What are the objectives to pursue in the recovery strategy?

Discuss and assess the relative importance of each objective (1 indicates that you perceive it as not important and 7 indicates that you perceive it as very important).

OBJECTIVES OF THE RECOVERY PLAN	1 (not important)						7 (very important)	
	1	2	3	4	5	6	7	
1. To minimise the radiological impact				11		1	11	5,6
2. To minimise the impact in the population (e.g. their living conditions)							111 1 11	7. Most frequent
3. To improve / increase the public confidence		1	1			1	11	5
4. To minimise the economic costs		11	1		11			3,4
5. To minimise the environmental impacts			1	11	1			4
Other objectives not included in the list:								

Q3. What are the main factors and key criteria for the strategy selection?

Assess the relative importance of the proposed criteria to be taken into account for the strategy selection (1 indicates that you perceive it as not important and 7 indicates that you perceive it as very important).

CRITERIA	1 (not important)					7 (very important)	
HEALTH	1	2	3	4	5	6	7	
1. Avoid doses				11	1		11	5,4
2. Psychological consequences						1	1111	6,8 1st
FEASIBILITY								
3. Technical	1		1		11		1	4,2
4. Logistics			1		111	1		3,4
5. Duration				1	11	1	1	5,4
6. Work force		1	1		1	1	1	4,6
ECONOMIC (EXPENSES AND BENEFITS FROM THE STRATEGY)								
7. Countermeasures cost	1	11	1		1			2,6
8. Avoided health costs		111	1		1			2,8
9. Infrastructure		1	1	11	1			3,6
10. Employment / human capital		1	1	1		11		4,2
ENVIRONMENTAL								
11. Impact on environmental compartments (air, water, soil)		1	1	11	1			3,6
12. Resource use			11	1	11			4,0
13. Waste production			1		11	1	1	5,2
14. Waste disposal			1		11	1	1	5,2
SOCIAL								
15. Community involvement				1		111	1	5,8
16. Community acceptance and satisfaction				1		111	1	5,8 2nd
17. Impacts on neighborhoods or regions (stigmatization)				11	1	1	1	5,2
18. Stakeholder concerns and trust				11		1	11	5,6
OTHER?								

Q4. What are the main uncertainties affecting the decision about the recovery strategy?

What is our opinion about different uncertainties that could affect the decision-making during the transition phase? Please, discuss it.

Category	Uncertainty
Environmental	• *How to identify and zone the affected areas?* • *How does the contamination change with time and what factors are implicated?* • *How could aquifers, groundwater be affected by the contamination?*
Economic	• *Are there enough resources – material, technical, human and funding - to face the recovery actions; the collection and analysis of environmental samples and the monitoring of the affected people?* • *Is there capacity to decontaminate the affected area? And to manage the waste generated?*
Health and Safety	• *How could a successful health surveillance plan that avoids negative reactions among the population, be designed and implemented ?* • *What are the psychological effects suffered by the population affected by the emergency?*
Social	• *Will people understand the actions that need to be undertaking?* • *How to ensure the follow-up of these measures?* • *Are they going to be accepted?* • *Will the public trust them?* • *Where and how is the population going to be relocated?* • *How would they be integrated in their new residence locations?*
Governance	• *Who, how, when to involve stakeholders?* • *How do address the preparedness of the actions during the transition phase?* • *How to coordinate them? Who is responsible for what? (roles and responsibilities)* • *How to report information to international organizations?*
Transversal	• *What (messages), Whom, How (mass media, social networks) and When to communicate?* • *What is the transition phase? Definition, timing, and coherence among international organism regarding the transition phase*

MAIN UNCERTAINTIES:
- WHAT TO DO WITH WASTES?
- HOW TO ENGAGE THE COMMUNITY WITH THE DECISIONS)
- DURATION?
- DATA CONCERNING THE NUMBERS OF CANCER AND IF THEY ARE FATAL OR NOT.
- DECISIONS ON RELOCATION.

PTO.

Q5 Choose the strategy you think it is best according to the previous discussion.

[NO RELOCATION
[LOW WASTE.

- NO DECISION.

[NO RELOCATION
[LOW WASTE.

- LOW WASTE.

- NO DECISION AND VOLUNTEER RELOCATION.

The summary of conclusions have been presented to all participants before the MCDA scenario based facilitated discussion.

It was agreed, that main concerns are:

- social impacts
- health impacts
- feasibility
- environmental + economical and other issues

The main objectives of the recovery plan are:

- Minimise impact in the population
- Minimise the radiological impact
- To improve public confidence

The discussion have started with following inputs:

Goal: Minimise impact in the population

Key criteria/attributes:

- Social impacts: **community involvement** and community acceptance
- Health impacts: psychological consequences and **avoid doses**
- Feasibility: duration and **workforce**
- Environmental: **waste production** and waste disposal
- Economic: employment – human capital

Uncertainties:

- What to do with wastes? → **waste production** → ***waste amount - H***
- How to engage the community? → **community involvement** → ***Willingness of population to cooperate on strategy implementation – S***
- Duration of the countermeasures implementation → dependent on **workforce** → ***number of workers needed – H***
- Data concerning the number of cancers → **avoid doses** → ***doses – H***
- Roles and decisions local versus regional and national authorities → **community involvement** → ***Willingness of population to cooperate on strategy implementation – S***

A selected group of 4 stakeholders who played a role of decision makers have acted as Crisis Centre at a stage and were observed and supported by the remaining participants of the workshop.

Discussion among the remaining participants in small groups was encouraged.

The crisis manager with the role "mayor" called in additional advisors to support her in the official discussion, thus forming a second group and providing in one voice their decisions.

The discussions were facilitated by experienced independent facilitators.

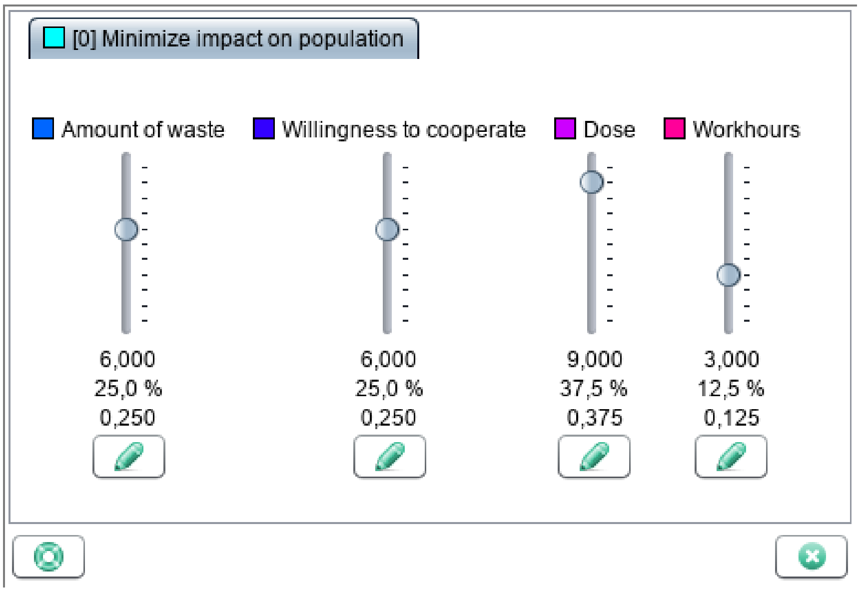
The MCDA tool was overhead presented during the ongoing discussion.

The values for the "hard" criteria such as waste amount, number of workers needed and doses have been taken directly from the JRodos calculation results. The values for the "soft" criterion as "Willingness of population to cooperate on strategy implementation" were estimated and agreed by the decision makers team with support from other participants.

Group/Criterion	Weight	Unit	Low waste	High waste	Do nothing	LW+Relocation	HW+Relocation
Minimize impact on population							
Amount of waste	0,25	[Mkg]	7,0	140,0	0,0E0	7,3	140,0
Willingness to cooperate	0,25	[]	high	medium	very low	medium	low
Dose	0,375	[mSv]	8,0	4,2	14,0	4,4	2,5
Workhours	0,125	[h]	3,7E5	2,3E6	0,0E0	3,7E5	2,3E6

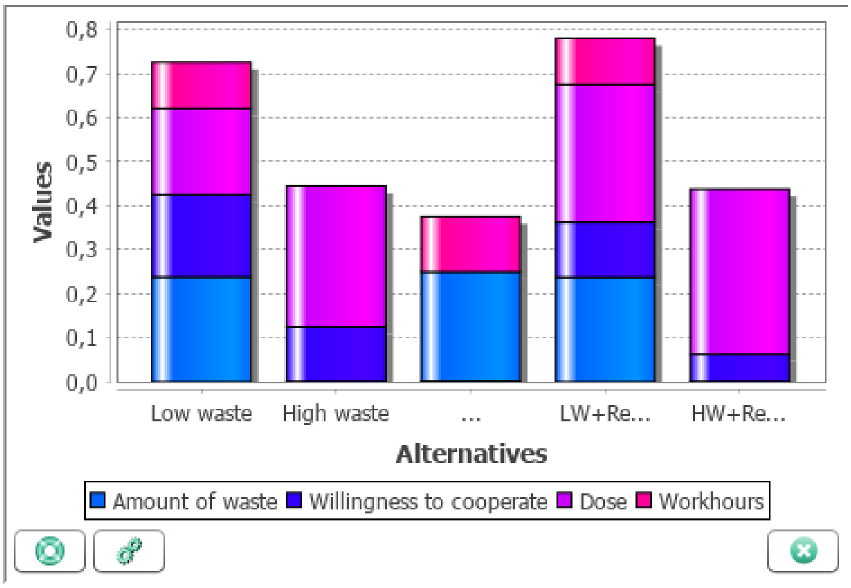
The thorough discussion in all groups took place during the estimation and agreement on the weights of criteria.

At that stage of discussion facilitators helped to interactively observe and evaluate the changes in criteria or weights using the MCDA tool.



The different opinions on the weights were investigated in the MCDA tool and then consolidated into one common agreement.

Having agreed on the initial weights for particular criteria they have been assessed to those using the MCDA tool. The resulting order of the strategies was uncovered and displayed to participants after the first iteration using the bar type of visualisation. Each criterion contributed with its weight to the final ranking of recovery strategies.



The stability of current ranking was discussed using the visualisation in the MCDA tool.

The tool was evaluated to be very helpful for decision makers as it helps a clear structuring of the important facts influencing the choice of an appropriate strategy. Additionally, it triggered interesting discussions on criteria meanings e.g. what “protect the health of the public” actually meant under these conditions, which helped the groups to better understand each other’s motivation. It was definitely recognized by participants that the tool has the supportive character and the results could not be taken directly as a tool result as final one. Political decisions as one of the factors influencing the decision was pointed out and experienced in the discussion transparently.