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Transparent and traceable decision making in off-site nuclear emergencies

Dissemination of achievements in the EVATECH Project of the FP5 Fission Programme

Use of decision analysis in nuclear emergencies

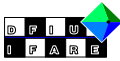
Palace of the Royal Flemish Academy of Belgium for Science and the Arts
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Slide 2


Use of decision analysis in nuclear emergencies

Overview

- Introduction to Decision Analysis
- Integration of Web-HIPRE into RODOS



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Decision Making

"Decision making is what you do when you are not sure **what to do?"**

Intuitive

- O.K. if it works and is possible

Programmed


- laws, applications, rules

Analytical


- characteristic in organizations
- definition of goals and priorities
- management of uncertain information
- evaluation of strategies

Decision making process:

- Identify a decision making situation
- Look for and list decision alternatives
- Select one alternative or create a compromise solution



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Decision Theories

von Neuman - Morgenstern (1947)



"Maximization of expected utility"

Axioms describing rational choices

Ordering of alternatives - must be able to compare alternatives

Dominance
A rational decision maker never adopts a "dominated" alternative

C is weaker than A and B in both attributes

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Cancellation
A choice between alternatives should **only** depend on those outcomes **that differ** for the alternatives

Transitivity

If $A \succ B$ and $B \succ C$ then $A \succ C$

Continuity
A gamble between the best and worst outcome should at one point (high odds) be preferred over a sure intermediate outcome

Invariance
The way of describing the alternatives should not affect the choice

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Decision Support

Motto:



Decisions have to be made - there is not always a single right decision - there can be many good ones

Goals

- **understand** the problem and help in the use of information
- help the DM to **make a choice**
- **explain** and justify the **choice** (or compromise)

Means

- **systems approach** is used to structure and define the problem: separate facts from values explicitly
- **understand the choice** by sensitivity analysis
what - if facts or values were different

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Decision Analysis

Problem area: Choices under noncommensurable and/or conflicting goals subject to uncertainty

A tool to clarify thinking and communication

Methods

- Decision tree / influence diagram / belief network**
 - successive choices subject to uncertainty
- Multiattribute utility theory**
 - choice under multiple criteria
 - uncertainty in data - comparison of lotteries
- Value tree**
 - multiple criteria model with no uncertainties
- The analytical hierarchy process (AHP)**
 - one way of doing a value tree analysis

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ENGINEERING RISK ANALYSIS

Statistical modelling of faults and maintainability



- reliability engineering
- safety analysis
- fault tree, event trees

DECISION ANALYSIS

is a way to handle multiple risk and cost components

(e.g. costs against safety)

Experts' and public's assessment and perception of risks is often different

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Public Policy Applications

Growing use of DA in participatory planning:
resource management, energy and environmental policy

Facilitated workshops:

- stakeholders
- decision analyst / facilitator
- experts
- interactive computer software

Results:
improved communication and transparency

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Value Tree Analysis: divide and conquer

- problem understanding by structuring into a value tree
- focus on one part of the problem at a time
- prioritizations clarify the most essential value dimensions

Steps

1. Structuring = definition of concepts, **alternatives**
2. Decision **criteria / attributes** = problem framing, value dimensions
3. Value **comparisons**, prioritization
4. **Sensitivity** = what - if analysis
5. **Learning** = reformulate the problem
return to the beginning
generate compromise alternatives

Decision analysis can be

- normative
- prescriptive
- **descriptive**

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Decision Analysis Process

Decision maker (- group)

Interested in:

- solving a problem
- being supported by decision analysis

Analyst

- helps in information collection and problem structuring
- explains the principles of the prioritization method
- acts as a discussant and consistency checker
- avoids influencing the decision

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Experts

- provide facts about problem areas

Computer software

- **interactiveness and instantaneous feedback is important**
- takes care of the computations
- visualizations help problem understanding
- can sometimes replace the analyst
- provides documentation

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Interactive Decision Analysis



Individual decision analysis interviews with computer support

Group processes:

Decision structuring dialogue:
create a learning environment

Facilitated workshops:
structuring, joint-learning, prioritization

Decision conference:
2 days of workshops
spontaneous decision conference (simplest form)


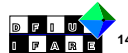
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Structuring

The greatest benefits are often due to structuring



- definition of decision alternatives
- are all the options feasible ?
- listing of essential factors (values = criteria = attributes)
- are the criteria independent
- do they discriminate the alternatives
- range of attribute / criteria scores
- hierarchical grouping and specification of criteria
- consensus on the terminology
- distinguish the details from the whole

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Preference Elicitation / Prioritization

- the alternatives define the decision framework
- comparison of the relative importance of criteria
- **explicit comparisons clarify the true meaning of the criteria**
- scores of the alternatives on the criteria
- overall priority scores and their components

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Sensitivity Analysis

- what - if considerations
- how easily does the ranking change by changing the prioritizations
- effects of new or omitted alternatives and criteria
- **builds confidence and commitment in the decision**

Result of the process

- elimination of irrelevant factors
- reveal areas of missing information
- improved communication
- learning
- **making a choice**
- reformulation of the problem

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Benefits of DA



- clarifies thinking - improved problem understanding
- **learning process is most important - not the numbers**
- **shifts focus from means to goals**
- increases creativity: compromise solutions and new perspectives
- **helps the use of expert judgements**

Political decision making

- facts and values can be kept separate
- limits and/or reveals deals made behind the curtains
- **decisions become justified explicitly**

Problems

- may create the feeling that there is a “one right” choice or model
- decision makers can hide behind the model
- the analyst can influence the decision



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Use of decision analysis in nuclear emergencies

Overview

- Introduction to Decision Analysis
- **Integration of Web-HIPRE into RODOS**

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The different phases of a nuclear emergency situation require different decision support approaches

Decision Support in different phases of emergency management

Continuous Implementation of Decision Support

R&D
Gather Criteria
Determine Relationships
Documentation

Create
Transparency

Assessment of
Strategies

Up until this point only exercises for the Early Phase (10 days)

Accident

Area-Wide Radiological Measurement Data

Time

Exercises

Early Phase
Civil Protection Measures

Late Phase
Long Term Measures

Reduction of Long Term Measures
-
Establishment of "Normal" Living Patterns

Evacuation
Sheltering
Distribution of stable iodine

Decontamination
Remediation
Relocation
Agricultural measures

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Source: Geldermann, J., Treitz, M., Bertsch, V. and Rentz, O. (2005) *Moderated Decision Support and Countermeasure Planning for off-site Emergency Management*, in: R. Loulou, J.-P. Wauaub and G. Zaccour (Eds.) *Energy and Environment: Modeling and Analysis*, Kluwer

D P I U
0 P A R E 19

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The Evaluation System (ESY) aims at providing transparency in the decision making process

Initial Status

- Due to the complexity of nuclear emergency management and the wide range of decision makers and stakeholders involved in the decision process, there is a need for a good evaluation system
- Reasons for Web-HIPRE
 - × Availability of different multi-criteria decision aid methods for the evaluation of strategies
 - × Possibility to re-structure the decision tree
 - × Feature of adding new strategies in the analyses
 - × Online training courses available through the WebSpace of the Systems Analysis Laboratory (SAL; Helsinki University of Technology)
- Requirements for an Implementation
 - × Web-HIPRE is an Applet communicating via a Servlet with the WebServer for saving and opening of files
 - × Interface between two sub-modules of the ESY
 - × Integration into the WebServer of the RODOS System

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Web-HIPRE is a software for problem structuring, multi-criteria evaluation and prioritisation

Web-based Decision Support

Web-HIPRE - Microsoft Internet Explorer

Web-HIPRE - Global Decision Support

Version 1.22
Version: 05/02/02

Web-HIPRE is a web-version of the HIPRE 3+ software for decision analysis, problem structuring, multi-criteria evaluation and prioritization. Follow links to [help](#), [slide show](#), or [download material](#) for more information.
You can create a private working directory by [registering](#) as a Web-HIPRE user.

Web-HIPRE is a Java-applet, so if there doesn't appear a new window containing the "Start Web-HIPRE"-button within a few seconds, you probably don't have a Java-enabled browser or you haven't selected "Enable Java" in the network preferences of your browser.

Bring Web-HIPRE to Front

Design: Raimo P. Härmäläinen
Programming: Antti Mustajoki

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Source:
Härmäläinen, R.P. and Mustajoki, J. (1998) *Web-HIPRE - Java Applet for Value Tree and AHP Analysis*, Computer software, SAL, Helsinki University of Technology, <http://www.hipre.hut.fi>

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0 P A R E 21

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Inclusion of the Menu-item „Import RODOS Model...“ in Web-HIPRE enables the functionality for the User

Screen-Shots of Web-HIPRE (File Menu)

The screenshot shows the 'File' menu of the Web-HIPRE application. The 'Import RODOS Model...' option is highlighted with a blue box and labeled '3'. A dialog box titled 'Import RODOS Model into WebHipre' is open, showing fields for 'Filename', 'Username' (set to 'public'), and 'Password', along with 'Import ESY' and 'Cancel' buttons. A warning message 'Achtung: Applet-Fenster' is visible at the bottom of the dialog.

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The multi-criteria based evaluation tool Web-HIPRE acts as the Evaluation Subsystem within RODOS

Attribute tree

Weighting of criteria

Radiolog. dose	0.900
Logistics	0.080
Costs	0.020

Decision table

	S.1	S.2	S.3	S.4	S.5	S.6	S.7
Waste (tons)	0	40	26.235	35.705	4.594	35.948	1.801.140
Work (man hours)	0	1.000	33.896	37.392	12.560	43.472	110.352
Costs (million €)	0	3	2	3	4	3	249
Avoided collective dose (manSv)	0	84	452	1.116	566	1.336	1.695
Avoided individual dose - area B (mSv)	0	87	69	177	187	177	219
Avoided individual dose - area C (mSv)	0	0	42	117	42	117	142
Avoided individual dose - area D (mSv)	0	0	19	42	19	61	80

Value function

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Various functions and methods of Web-HIPRE provide support for the decision makers

Functionalities of Web-HIPRE

The 'Composite Priorities' dialog illustrates the results of the analysis, showing a bar chart where the 'Overall goal' is the most significant criterion, followed by 'Radiolog. dose', 'Logistics', and 'Costs'.

The 'Explanation Module generates natural language reports to explain the results of the analysis

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The generic Explanation Module explains the results of the evaluation tool Web-HIPRE

Explanation Module

- The generic Explanation Module consists of a natural language generator which outputs two reports in accordance with the user's requests
 - The **comparative report** compares two alternatives to each other relative to one (or several) objective(s) (The content of the messages depends on the type of the selected objective(s))
 - The **sensitivity analysis report** interprets the results of a sensitivity analysis on the weight of an objective
- Preparatory Work**
 - Papamichail, K.N. (2000) Intelligent decision support for nuclear emergencies, PhD Thesis, The University of Manchester
 - Papamichail, K.N. and French, S. (2003) Explaining and Justifying the Advice of a Decision Support System: a Natural Language Generation Approach, Expert Systems with Applications, 24(1), pp. 35-48
- The generic Explanation Module constitutes a contribution to the direct involvement of decision makers

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The comparative report compares two alternatives to each other relative to an objective

The comparative report...

- ... determines how much better one alternative is over another
- ... arguments for or against a choice
- ... identifies whether or not an objective differentiates between two alternatives
- ... detects the most significant factors in the ranking of alternatives

Comparative Report

Comparison of S 1 and S 2 with respect to *Overall goal* and *Radiolog. dose*

Overall goal

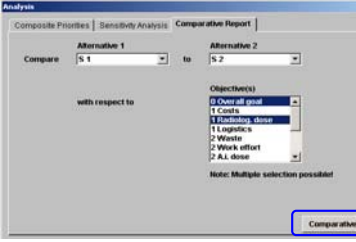


S 1 provides slightly lower *Overall goal* than S 2.

- This judgement takes into account the effects of *Radiolog. dose*, *Logistics* and *Costs*.
- While *Logistics* is the main reason to prefer S 1, this is outweighed by considerations of *Radiolog. dose* which provides motivation for preferring S 2.

Radiolog. dose

Radiolog. dose is a significant factor favouring S 2 over S 1.

- This judgement takes into account the effects of *A.c. dose* and *A.i. dose*.
- The importance of *Radiolog. dose* in determining *Overall goal* is so great that the relatively small difference between S 1 and S 2 is nevertheless significant in this case.
- S 1 provides slightly lower *Radiolog. dose* than S 2.
- S 2 is at least as good as S 1 on all subobjectives of *Radiolog. dose*.
- A.i. dose* provides the most important reason.
- Radiolog. dose* accounts for 90.0 percent of the determination of *Overall goal*.

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The sensitivity analysis report interprets the results of a sensitivity analysis on the weight of an objective

The sensitivity analysis report ...

- ... explains a sensitivity analysis graph
- ... shows the effect of changing the weight of an objective
- ... gives an overall assessment of the decision parameters

Sensitivity Analysis Report

Sensitivity Analysis for *Overall goal* on the weight of *Radiolog. dose*

This analysis examines how robust the choice of an alternative is to changes of the weight of *Radiolog. dose*.

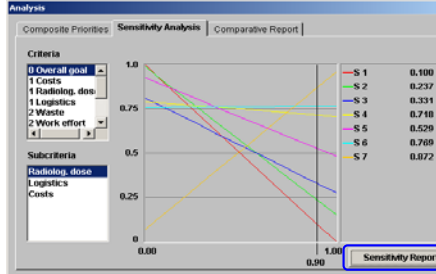


The lines in the graph of the sensitivity analysis, each associated with one strategy, show the weighted scores of the (associated) strategies when the weight of *Radiolog. dose* is varied from 0% to 100%. The vertical line at 90.0 represents the status quo. The overall scores of the alternatives are:

Alternative	Overall Score
S 1	0.100
S 2	0.237
S 3	0.331
S 4	0.718
S 5	0.529
S 6	0.769
S 7	0.872

The ranges of the weights of *Radiolog. dose* for which an alternative is the most preferred are:

Weight range	Alternative
0.00 - 4.92	S 1
4.92 - 15.82	S 2
15.82 - 36.91	S 5
36.91 - 78.38	S 6
78.38 - 100.00	S 7

The percentage on *Radiolog. dose* can be changed by as much as 11.62% without changing the optimality of S 7.

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Templates provide background information about objectives, benefits and target groups/areas of a measure

Opening a Template

The originator of this template is A.F. Nisbet (NRPB, UK)

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Template created for STRATEGY
Processing of milk for subsequent 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.

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Evaluation and elicitation process in Web-HIPRE

Source:
 French, S. (2000) Decision Support, Data Assimilation and Uncertainty Handling within RODOS, in: J. Ehrhardt and A. Weiss (Eds.) RODOS: Decision Support System for Off-Site Nuclear Emergency Management in Europe, Luxembourg, EUR 19144 EN.
 Geldermann, J., Bertsch, V. and Rentz, O. (2005) Multi-criteria Decision Support for Emergency and Remediation Management - Preference Elicitation and Evaluation of Strategies, 61st Meeting of the EURO Working Group "Multiple Criteria Decision Aiding", Luxembourg.

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Conclusions

- Emergency situations necessitate a coherent and effective emergency management involving complex decisions
 - × Conflicting objectives must be resolved
 - × Priorities must be set
 - × Perspectives of many stakeholder groups must be brought into some form of consensus
- The application of the RODOS system including Web-HIPRE ensures transparency during the decision making process
 - × The integration of an explanation module into the evaluation tool Web-HIPRE contributes to the direct involvement of the decision makers and helps to form an audit trail
 - × Sensitivity analyses are important for the robustness of a decision since input parameters of a decision making model may be subject to uncertainties
- Decision making workshops are important emergency exercises, they allow the identification of relevant decision criteria and feasible countermeasures and ensure that the attribute tree is a reasonable basis for decision making
- In order to improve the operational applicability of the whole system, further developments are necessary involving advanced multi-criteria methods that take approaches for uncertainty modelling and sequential decision making into account → EURANOS* project (6th Framework Programme)

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*EURANOS: European approach to nuclear and radiological emergency management and rehabilitation strategies, <http://www.euranos.tzk.de>


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