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EURANOS

MULTI-DIMENSIONAL SENSITIVITY ANALYSIS FOR MULTI-ATTRIBUTE DECISION MAKING UNDER PREFERENTIAL UNCERTAINTY

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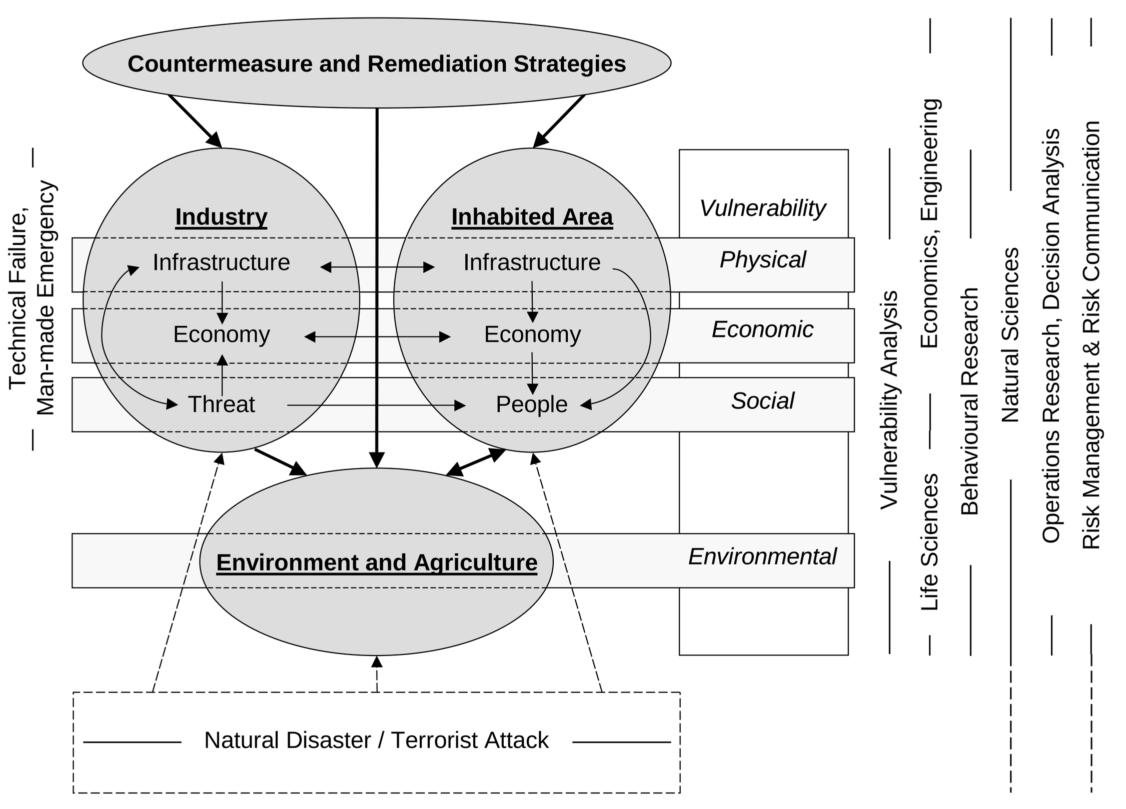
Decision Support for Industrial Risk Management

In modern industrial production networks and their external environment, complex decision situations need to be resolved with respect to their potential impact on the society in a wide variety of circumstances. The complexity of contemporary production systems and an increased environmental vulnerability indicate that current problems with industrial risk management require a rethinking of safety management (UNISDR, 2002). In order to handle potential risks to and emanating from the industry and consequently to mankind as well as the environment, an integrated approach to risk management and industrial environmental policy is needed. Usually, various scientific expert groups are involved with heterogeneous technical background knowledge in different disciplines. Know-how from economic, ecological, engineering and natural sciences must be brought together, taking into account political and socio-psychological factors. Approaches from Multi-Criteria Decision Analysis (MCDA) can help to consider various incommensurable levels of information and to take into account the (subjective) preferences of the responsible decision makers and thus contribute to transparency and traceability of decision making processes (Belton and Stewart, 2002; Geldermann et al., 2007).

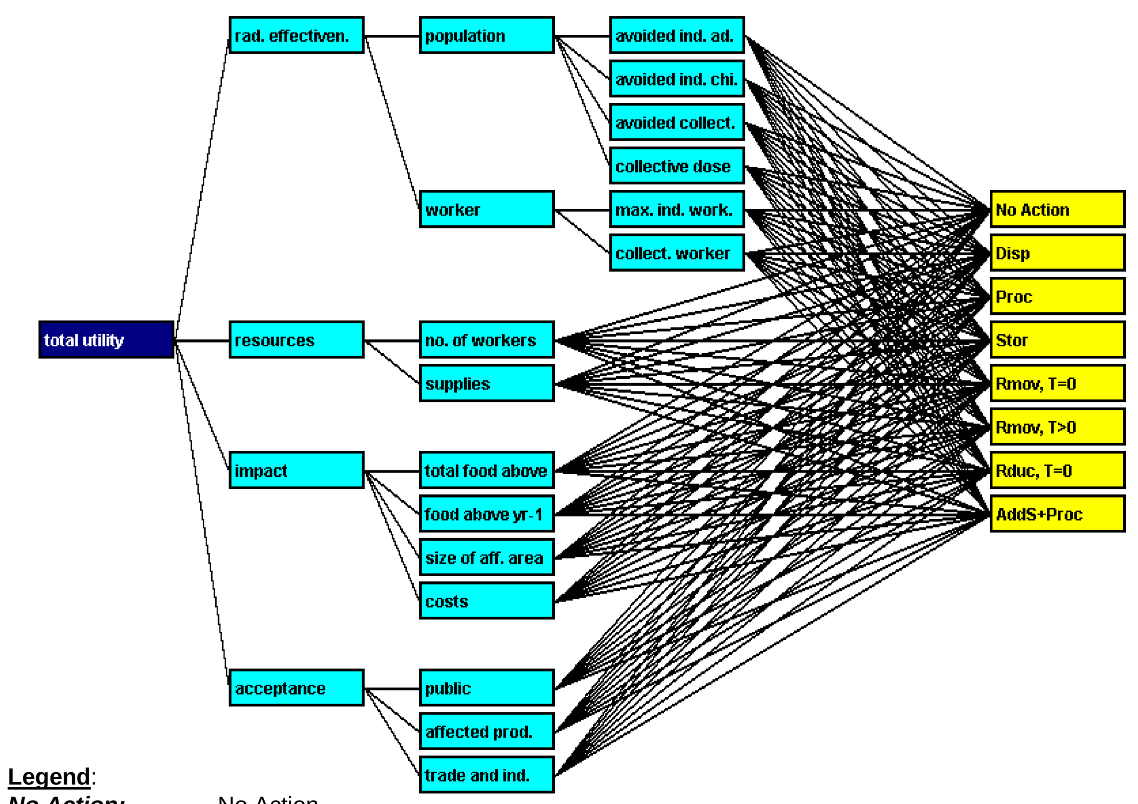


- Affecting essentially all parts of any industrial production system, energy supply is a very important part of critical infrastructure.
- Critical infrastructure can be severely damaged, destroyed or disrupted by technical failure (accidents), human failure (negligence), natural disasters, criminal activity or acts of terrorism leading to supply interruptions which may have a severe impact on industry and economy as well as the society as a whole (EC, 2005). Thus, crisis situations in the energy sector constitute a special challenge.
- Risk management and emergency planning are especially important in nuclear power generation since a large part of electricity is generated by nuclear energy (in Europe as well as world-wide) and because of the resulting severe and far-reaching consequences of an emergency.
- A flexible decision support system providing reliable information and guidance is needed. In particular, the evaluation of long-term remediation strategies after a nuclear or radiological emergency can benefit from operationally applicable multi-criteria methods and evaluation techniques to guide and support the responsible decision makers in the decision making process.

Uncertainty Handling in Multi-Criteria Decision Support for Nuclear Emergency and Remediation Management

The Decision Support System **RODOS** is designed to support decision making throughout all phases of nuclear emergency management (see: www.rodos.fzk.de). Its conceptual structure includes three subsystems:

- The **Analysing Subsystem (ASY)** processes incoming data and forecasts the location and quantity of contamination based upon monitoring and meteorological data and models including temporal variation. *Arising uncertainties*:
  - Input data of the ASY (source term and meteorological fields)
  - Model imperfectness
  - Parameter uncertainties
- The modules of the **Countermeasure Subsystem (CSY)** simulate potential countermeasures, check them for feasibility and calculate their consequences. *Arising uncertainties*:
  - Model imperfectness
  - Parameter uncertainties
- Web-HIPRE (see Mustajoki and Hämäläinen, 2000), a tool for MCDA, has been integrated into RODOS as **Evaluation Subsystem (ESY)** to support a team of decision makers in evaluating the overall efficacy of different countermeasure or recovery strategies according to their potential benefits/drawbacks (quantified by the CSY) and preference weights (provided by the decision makers). *Arising uncertainties*:
  - Model imperfectness
  - Parameter uncertainties



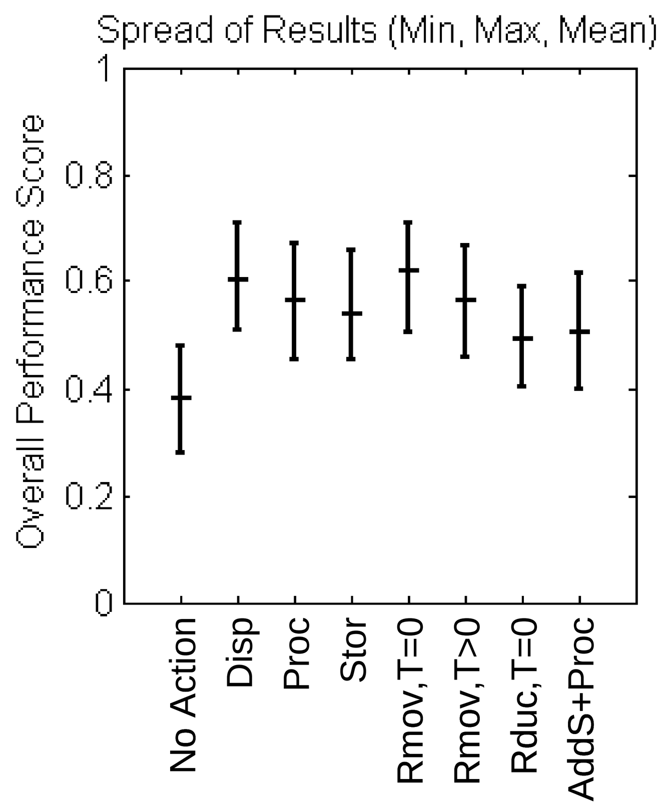
Legend:

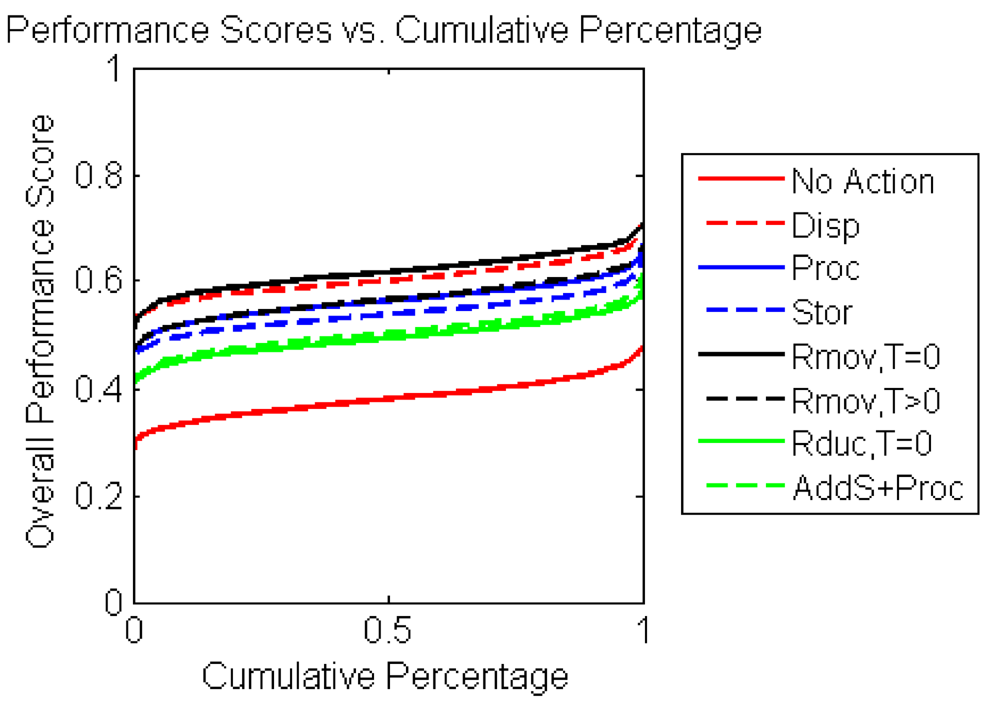
No Action:	No Action
Disp:	Disposal (of the produced milk)
Proc:	Processing (of milk)
Stor:	Storage
Rmov, T=0:	Removal of cows from contaminated feed at time T=0, feeding with uncontaminated feed
Rmov, T>0:	Removal of cows from contaminated feed at time T>0, feeding with uncontaminated feed
Rduc, T=0:	Animals get uncontaminated / less contaminated feed
AddS+Proc:	Adding of concentrates to the food that reduce the activity concentration (of milk and meat) and subsequent processing

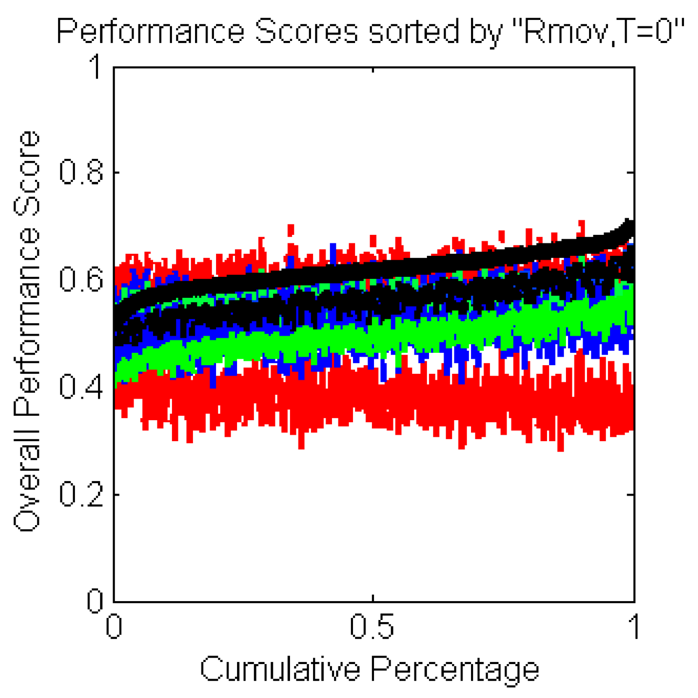
- Decision processes are usually affected by various sources of uncertainty which can be classified in different ways (cf. e.g. French, 1995). From the point of view of MCDA, a distinction can be made between *data uncertainties* (related to the consequences of the alternatives), *preferential uncertainties* (introduced during the elicitation of the alternatives) and *model uncertainties* (pertaining to the structure of an MCDA model).
- In multi-attribute value theory (MAVT), preferential information is modelled by weighting factors (i.e. *inter-criteria* comparisons) and value functions (i.e. *intra-criteria* preferences).
- The preferential uncertainties need to be handled appropriately.
- Classical one-dimensional sensitivity analysis:
  - Helps to assess the robustness of a decision with respect to weight changes.
  - Major drawback: procedure is limited to varying one weight at a time.
- A **multi-dimensional sensitivity analysis approach** is needed allowing to explore the impact of the simultaneous variation of several weights as well as the value functions' shapes is needed (inter-criteria and intra-criteria preference parameters):
  - Facilitation of the difficult process of preference elicitation.
  - Contribution to an easier way of achieving consensus in group decision processes.
- **Monte Carlo simulation** can be used to draw samples of parameters within afore assigned intervals (Bertsch et al., 2006).

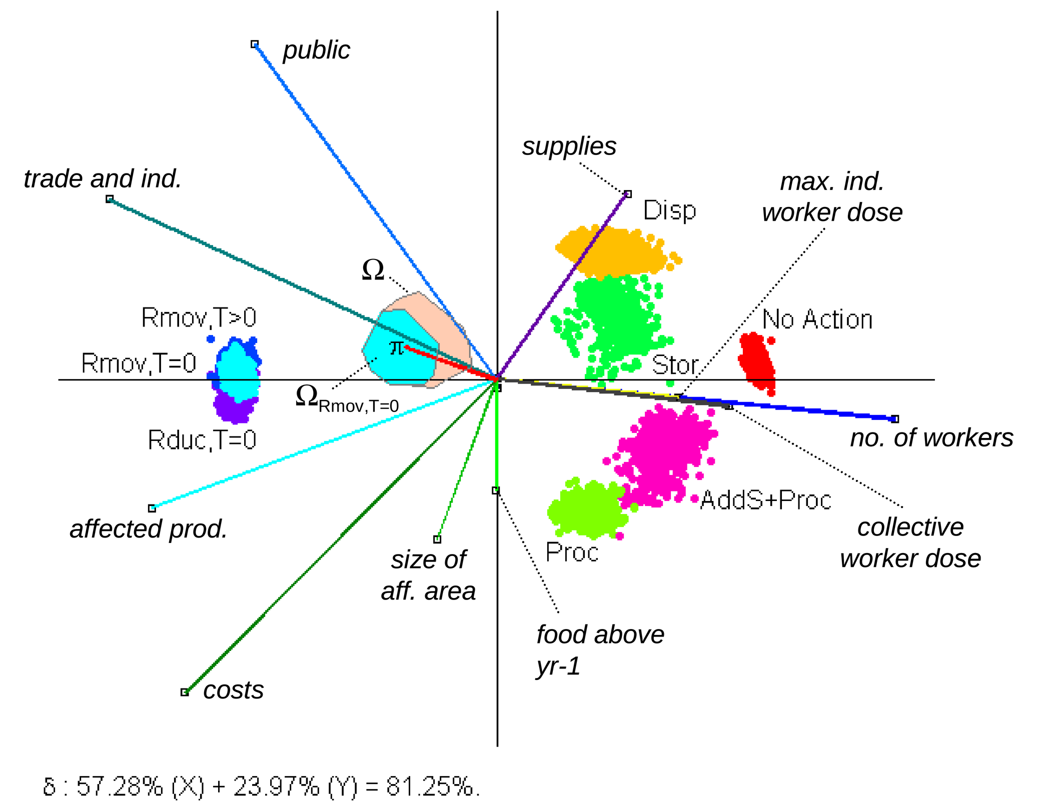
Visualisation of Results

Multi-dimensional sensitivity analysis allows to illustrated the ranges in which the results can vary in consequence of the preferential uncertainties and helps to identify dominating or dominated alternatives (left). Plotting the performance scores against the cumulative percentage provides insight into the relative frequency of the performance scores of the different alternatives (second from the left, cf. also Butler et al., 1997). Sorting the performance scores in ascending order of the performance score of a chosen alternative allows to read off information about the percentage at which the chosen alternative is ranked first (second from the right, cf. also Bertsch et al., 2007). Combining the multi-dimensional sensitivity analysis approach with principal components analysis (PCA) provides a good overview of the impact of the complete preferential uncertainty on the results and allows to graphically explore the distinguishability of the alternatives from a preferential perspective (right).









Conclusions and Outlook

- Allowing an adequate modelling and visualisation of the preferential uncertainties arising in a decision making process in the context of nuclear emergency and remediation management, a new multi-dimensional sensitivity analysis approach is proposed.
- The approach can provide valuable insights into the robustness of a decision and also allows to explore trade-offs between conflicting objectives (such as "radiological effectiveness" and "resources"). The results for the considered case study have shown that "Rmov,T=0" is ranked first for 63% of the drawn parameter combinations while "Disposal" and "Processing" receive the highest score for 34% and 3% respectively. All other alternatives are dominated by these three and can thus be eliminated from debate.
- The knowledge acquired by conducting such comprehensive analyses in the context of the case study can also be used for countermeasure planning purposes, and can consequently contribute to an improved emergency preparedness.
- It is now planned, to test and evaluate the approach in further decision making workshops in order to ensure that it meets the needs of decision making processes in practice.
- Furthermore, it is planned to extend the approach towards sequential decision making in order to be able to reflect the sequential and iterative character of practical decisions in MCDA models.

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