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

EUROPEAN JOINT PROGRAMME FOR THE INTEGRATION OF RADIATION PROTECTION RESEARCH
CONCERT

Robust decision making

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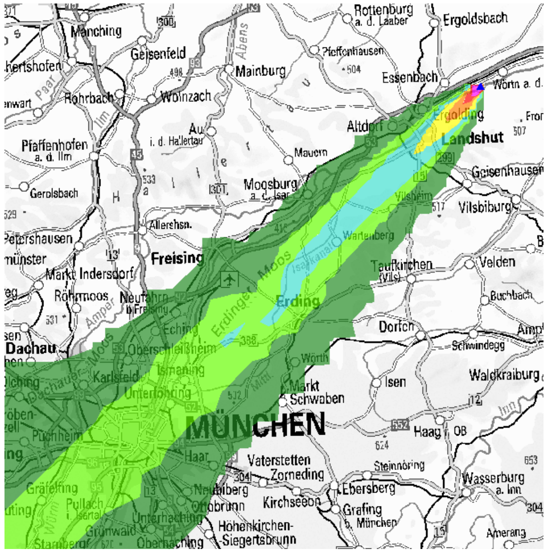

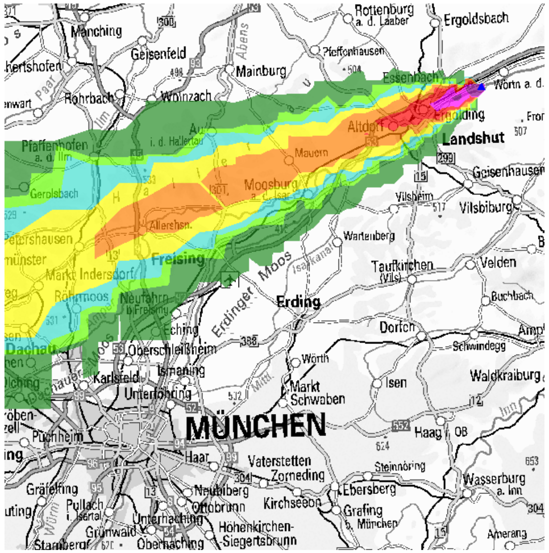

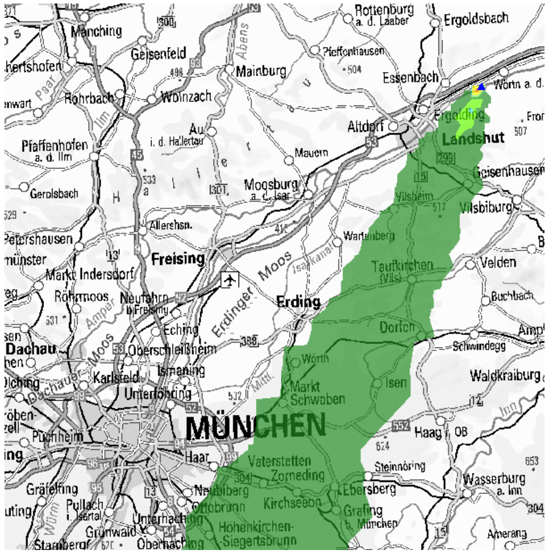

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What do we mean with „robust“ decision making

- Support a structured decision-making process towards an “acceptable” countermeasure strategy
  - In the presence of deep uncertainty about potential outcomes
  - Taking into account multiple criteria (e.g. dose, cost, social acceptance for various stakeholders)
  - With a socially acceptable justification of decisions (e.g. from an ethical point of view)
- In an emergency, scenarios are used to describe an event; thus decision making should be support throughout the different phases of that scenario assessment
  - By using a DSS or simulation model to understand the radiological situation and develop countermeasures
  - To evaluate countermeasure strategies

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Robustness indicators

- Decision making heavily relies on the use of results from simulation models, either part of European decision support systems or specialized models that might be used for a particular purpose
  - So far deterministic results are presented
  - As part of CONFIDENCE, ensembles of meteorological forecast data are used to describe the variability of the weather
  - Source terms also are very variable
  - One objective is to develop indicators that mark a result as “more or less” appropriate for decision making
  - Indicators might be most important in the very early phase as decisions on e.g. evacuation should be best taken before the release starts based on very limited/uncertain information
- Indicators should be also developed for the evaluation of strategies in the later phase using MCDA
- Indicators should be self explaining

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Indicators – discussion of ideas

- Indicators with 5 colours (3 are insufficient to discriminate)

Endpoint	Early phase (pre-release and release)	Early phase based on ensemble modelling*	Early phase based on data assimilation (food and source term) **	Transition phase	Long-term recovery phase
Dose maps	red	yellow	red-yellow	yellow	green
Dose rate maps	red	yellow	red-yellow	yellow	green
Countermeasure areas	red-yellow	yellow	red-yellow	yellow	green
Plume arrival time	red-yellow	yellow	n.a.	n.a.	n.a.
Concentration in feed and foodstuffs	red	yellow	yellow-green	yellow	green
Concentration in rivers from run-off	red	n.a.	n.a.	yellow	n.a.
Concentration in rivers from direct release	red-yellow	n.a.	n.a.	yellow	yellow
Concentration in lakes and reservoirs	red	n.a.	n.a.	yellow	yellow
Concentration in marine food products	red	n.a.	n.a.	yellow	yellow
Inhabited area countermeasures	red	yellow	yellow	yellow	green
Food countermeasures	red	yellow	yellow	yellow	green

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Discussion

- Ample indicators are widely used – traffic light
- Problem might result from red-green blindness; special hatching/shading might be introduced
- General problem: how to define the “added value” and the “uncertainty” of a particular result for the decision maker
- Are particular results less sensitive against uncertainties?

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How to realise this

- Take the scheme from the French food identification with 5 colours and characters A to E
- Define critical input parameters (e.g. source term and weather) in user input windows (e.g. RODOS-Lite) with changeable classification number
- Default value is D (or E for source term?). The user can change them according to information available and define even A (B) for exercises
- Define rules how the input classification is used for individual results
  - If two different grades are given in the input (e.g. source term D and weather C), take the worst one for the result, e.g. D
  - Weather data from re-analysis is one grade better than the prognostic data
  - If mixed quality of input is given (e.g. weather data from re-analysis and prognosis), the worst one is used
  - If results are based on monitoring, the second grade (B) is indicated
  - For some aggregated results (e.g. areas for countermeasures) the grade is +1 of that from the worst input

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Indicators examples

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Examples

- Input in JRodos GUI
- Results
  - Result tree
  - Result map

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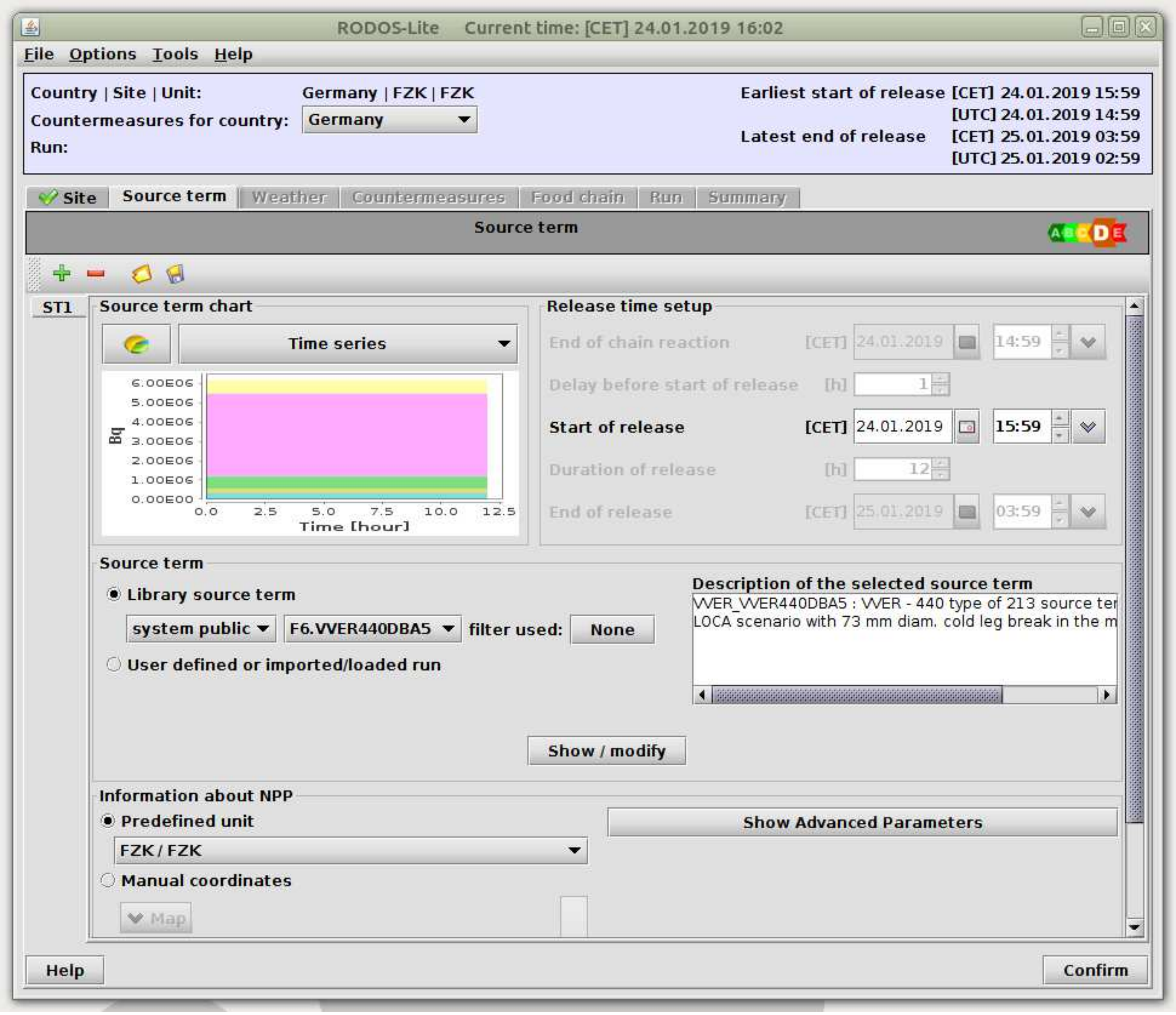
Input source term



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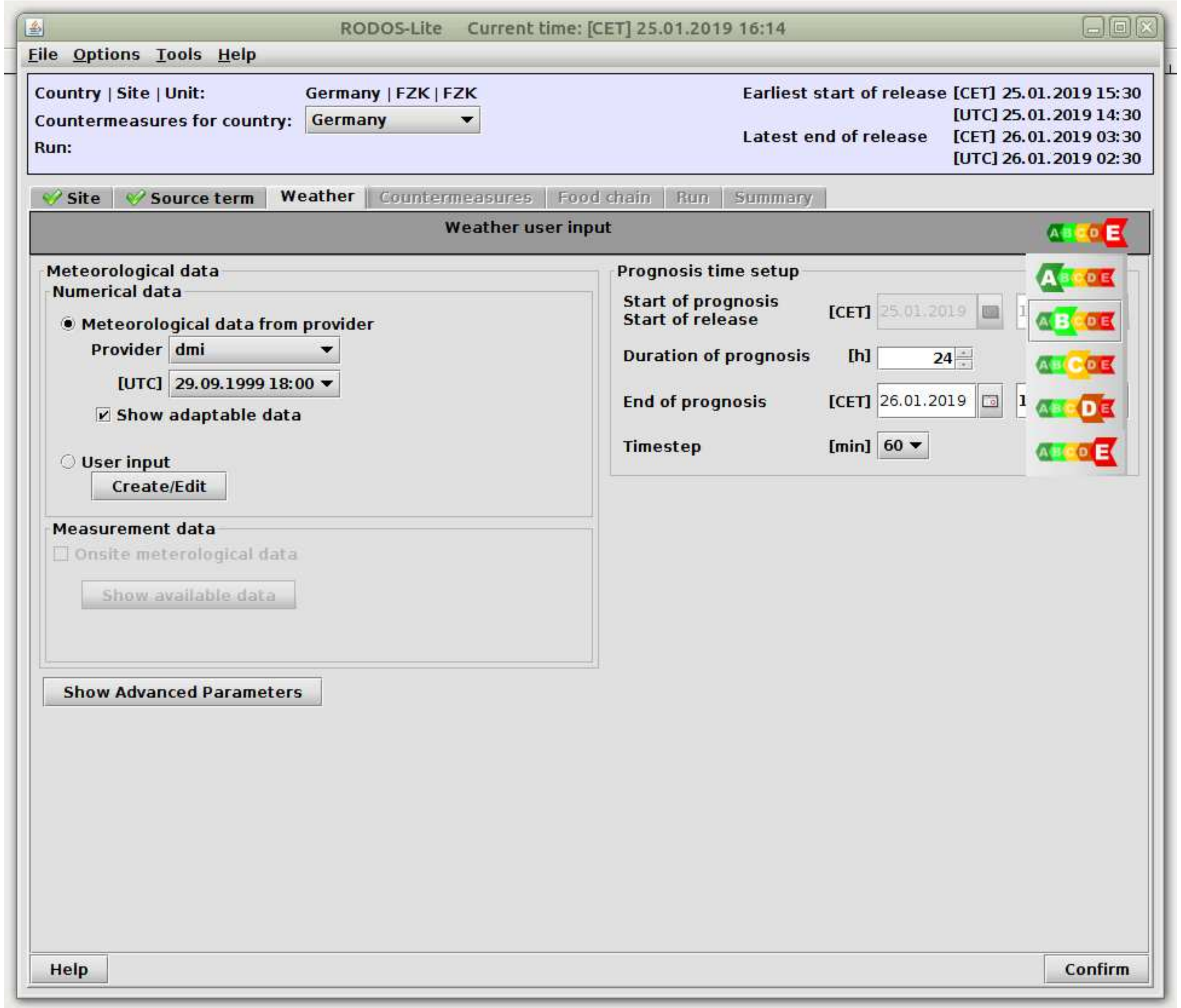
Input weather



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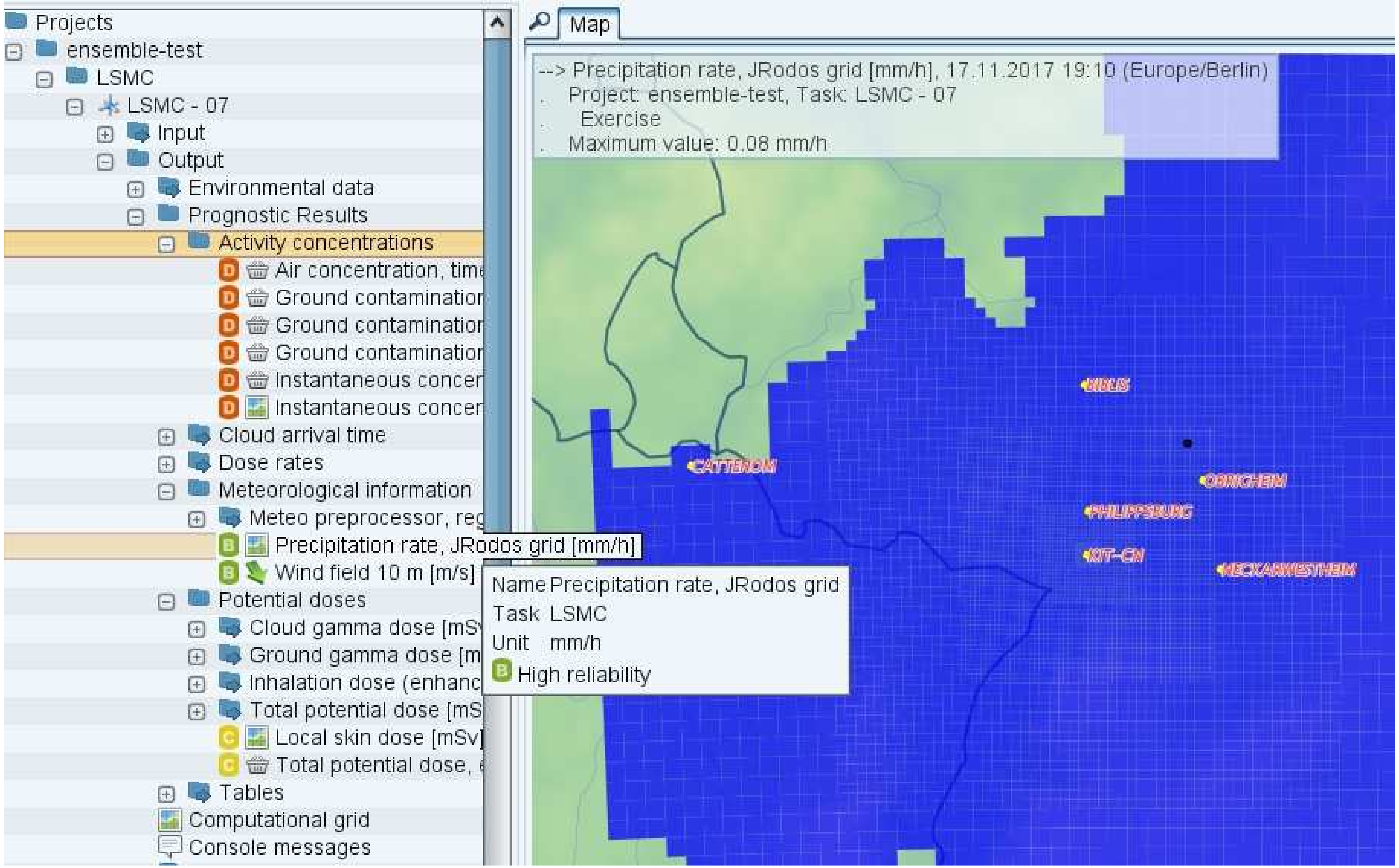
Indicator in tree



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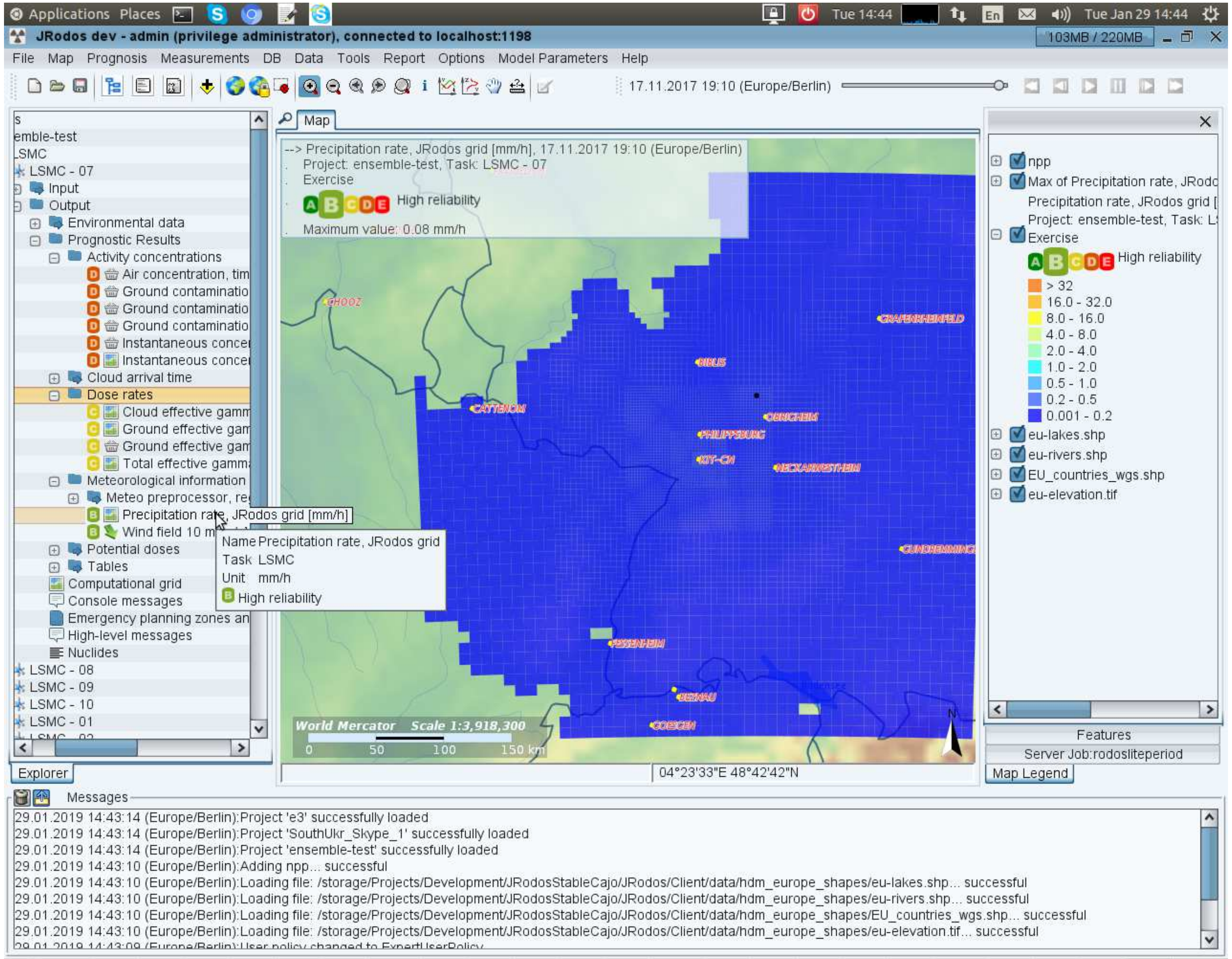
Indicator map result



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Evaluation indicators

Description of proposal	Can these indicators help you in decision making - ranking (6 very helpful , 1 not helpful at all)
Are indicators a good idea to improve the selection of appropriate results and indicate the uncertainty linked to a result?	
If yes, is a color code an appropriate mean to indicate this?	
Is the selected scheme with 5 colors based on the French food system appropriate?	

Robustness in Multi-criteria Decision Aid

- Different interpretations (Dias, 2006; Hites *et al* 2006)

- Robustness of a decision is a measure of its flexibility:
  - → the potential of a decision taken at a given moment to allow for achieving near-optimal states in the future, in conditions of uncertainty (Rosenhead *et al* 1972)
  - → one that is always near, or does not contradict solutions corresponding to other admissible (model) parameter instances (Vincke 1999) → can be extended to different scenarios.

- Robustness analysis is the process of elaborating recommendations founded on robust conclusions.

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Various approaches identified, e.g.:

- Maximin
- Expected value based
- Info-Gap based

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Maximin

- "Best performance under worst conditions"
- Based on Wald metric (Wald 1950) which associates to any decision alternative *a* its worst-case performance.

$$R(a)= \min \{ f(a, s) \mid s \text{ scenario}\},$$

where f(*a*, *s*) is the performance of alternative *a* under scenario s

(scenario =a plausible combination of model data and parameters).

  - This metric is associated with a pessimistic point of view as it assumes that the worst will happen.

- The decision option maximising R (the *maximin* solution) corresponds to the absolute robust solution in the sense of Kouvelis and Yu (1997).

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Expected value based indicators

- When external uncertainties are modelled in a probabilistic way, the robustness of a decision alternative *a* can be assessed as (Walsh et al, 2013):

$$R(a) = E(Functionality\ (a)) = \int_S Functionality(a, s) \cdot p(s) ds,$$

where Functionality (a,s)=Success (a,s) – Failure (a,s) /T

T = tolerance

p(s) is the probability of scenario *s*.

- The decision option maximising R is the most robust solution

- When the distribution p is unknown, the arithmetic average could be used instead (Laplace's principle of insufficient reason).

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Info-Gap based indicator

- Info Gap Decision Theory (IGDT) (Ben-Haim, 2006) was introduced to assist decision-making when
  - both the performance of alternatives and the probability of scenarios are uncertain and
  - probabilistic models of uncertainty are unreliable, inappropriate, or unavailable.
- The robustness of a decision alternative *a* is defined as:

$$R(a, E_c) = \max \{\alpha \mid E(a) \geq E_c\},$$

where the performance of a doesn't vary with more than a fraction α from its nominal value (idem for probability p of scenarios)

E(a) is the expected utility of a

E_c is the critical, i.e. minimal acceptable value, for the utility of a

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How MCDA with uncertainties is used

- Practical Robustness indicators for the MCDA are difficult to define
- In general, a solution/strategy should be applicable to as many as possible realisations of the scenario (realisations of the scenario can be an ensemble simulation)
- Example
  - Ensemble of 30 weather realisations with equal probabilities times 3 source terms with different probabilities = 90 realisations, each with a particular probability
  - Strategies with a given preference setting can be tested against these ensembles by repeated MCDA. The MCDA is applied to each of the realisations and the results are weighted with their probabilities
  - If realisations are not enumerable anymore, use histograms and ensemble techniques instead with MCDA applied many times (>1000)
  - The strategy that is successful for a given threshold (e.g. sum of weighted realisations count) higher than a given robustness indictor can be regarded as robust

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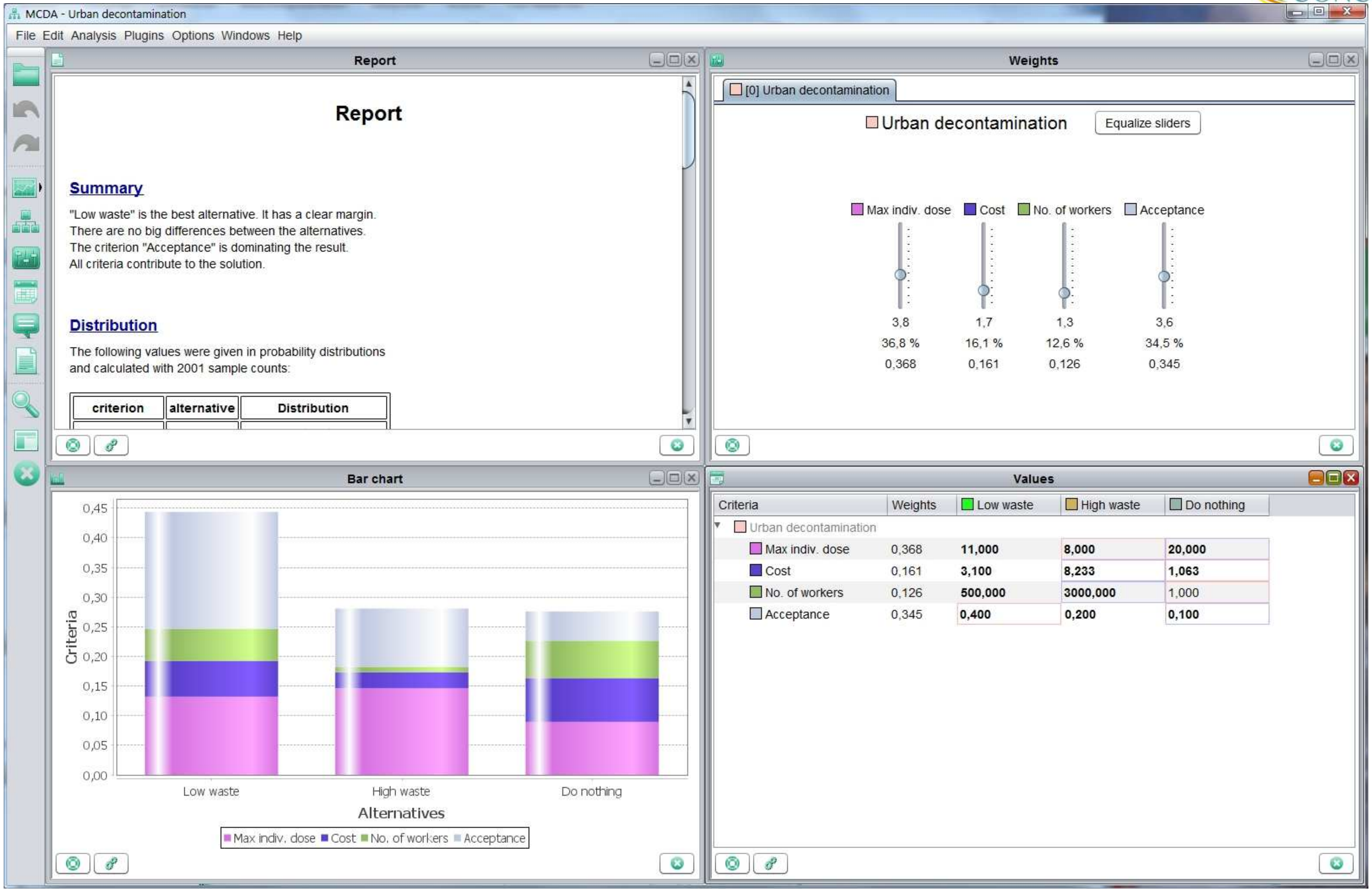
Main window of MCDA



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Uncertainties as input function

Define value function for "Low waste" of "No. of workers":

Functions are not limited.

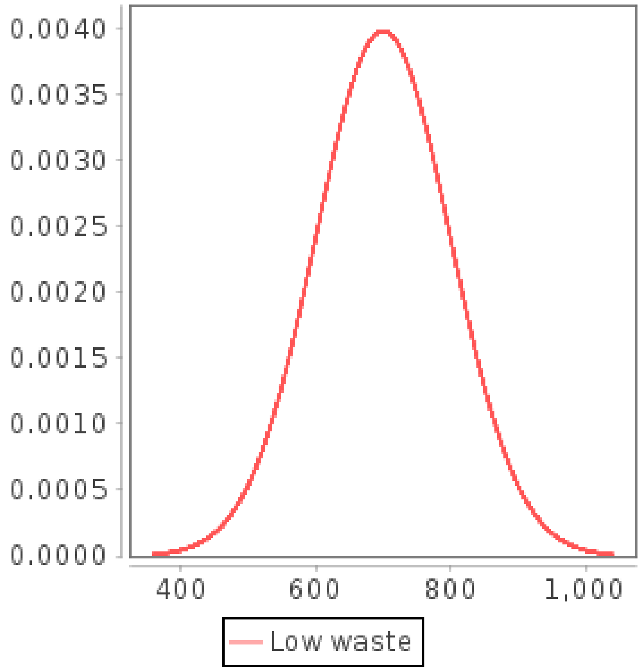
Normal Distribution ▾

Normal Distribution

Input value for mean: 700.0

Input value for standard deviation: 100.0

Show



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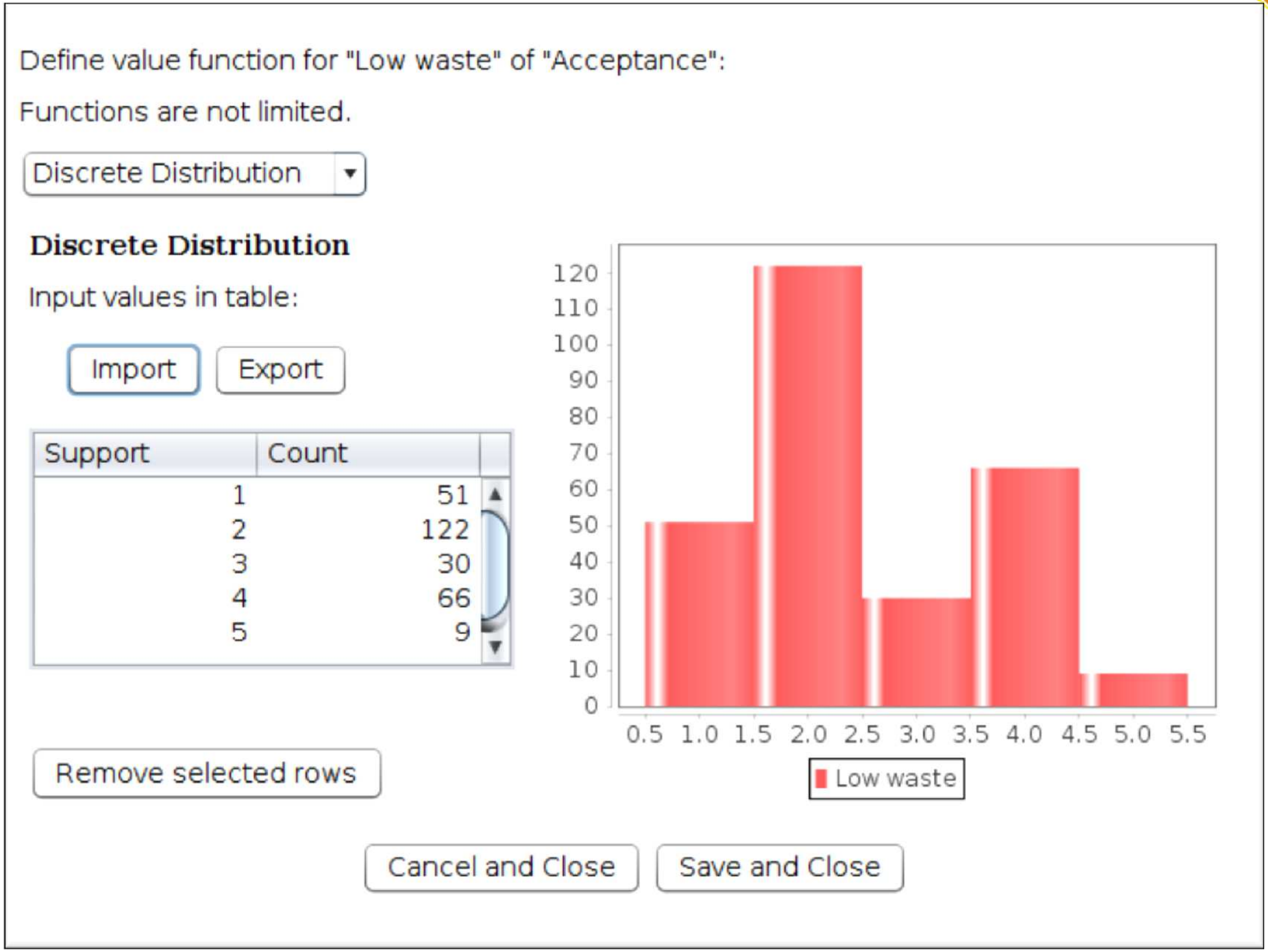
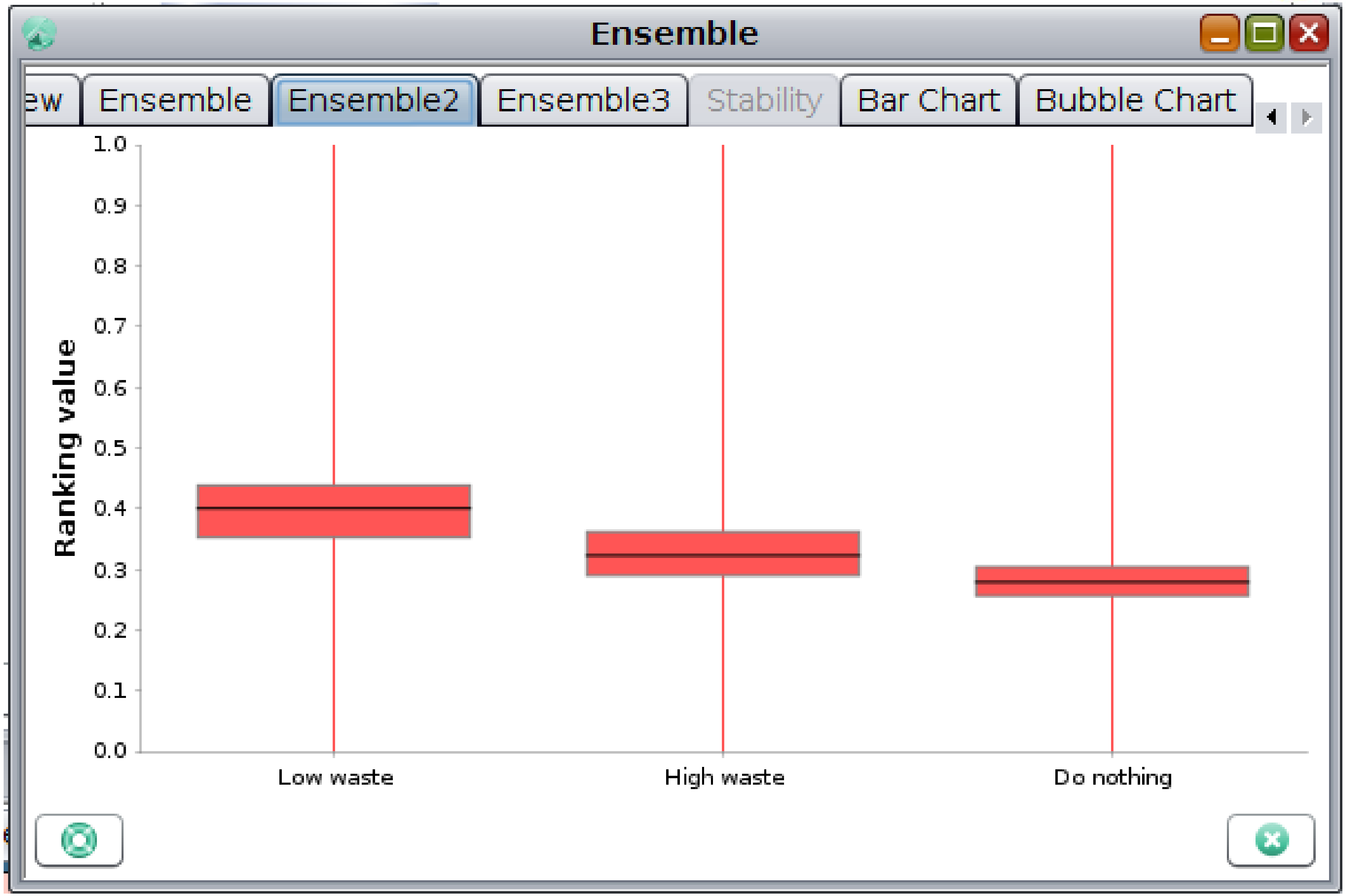
Uncertainties as input from models



Uncertainties in result presentation



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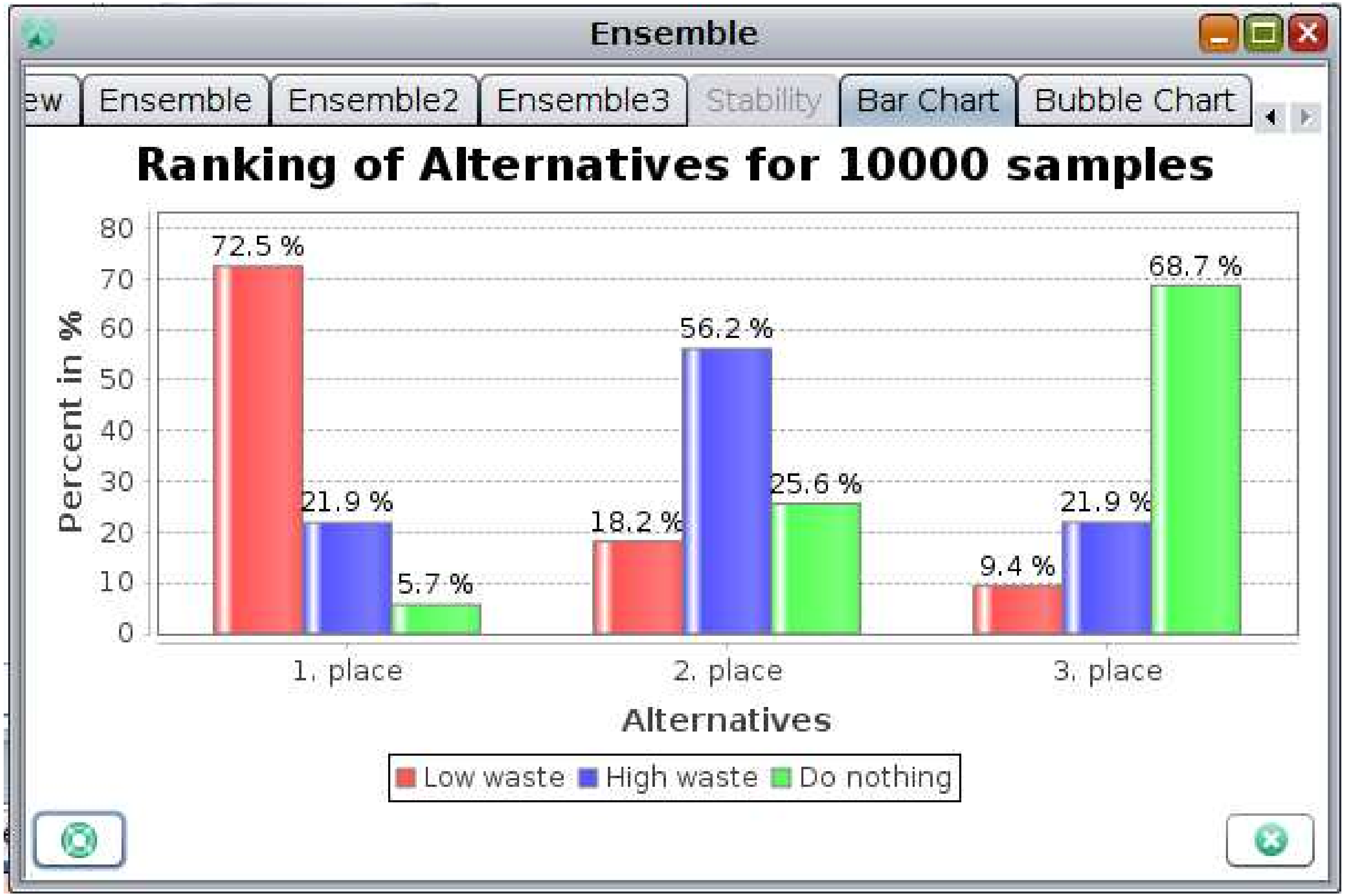
Uncertainties in result presentation



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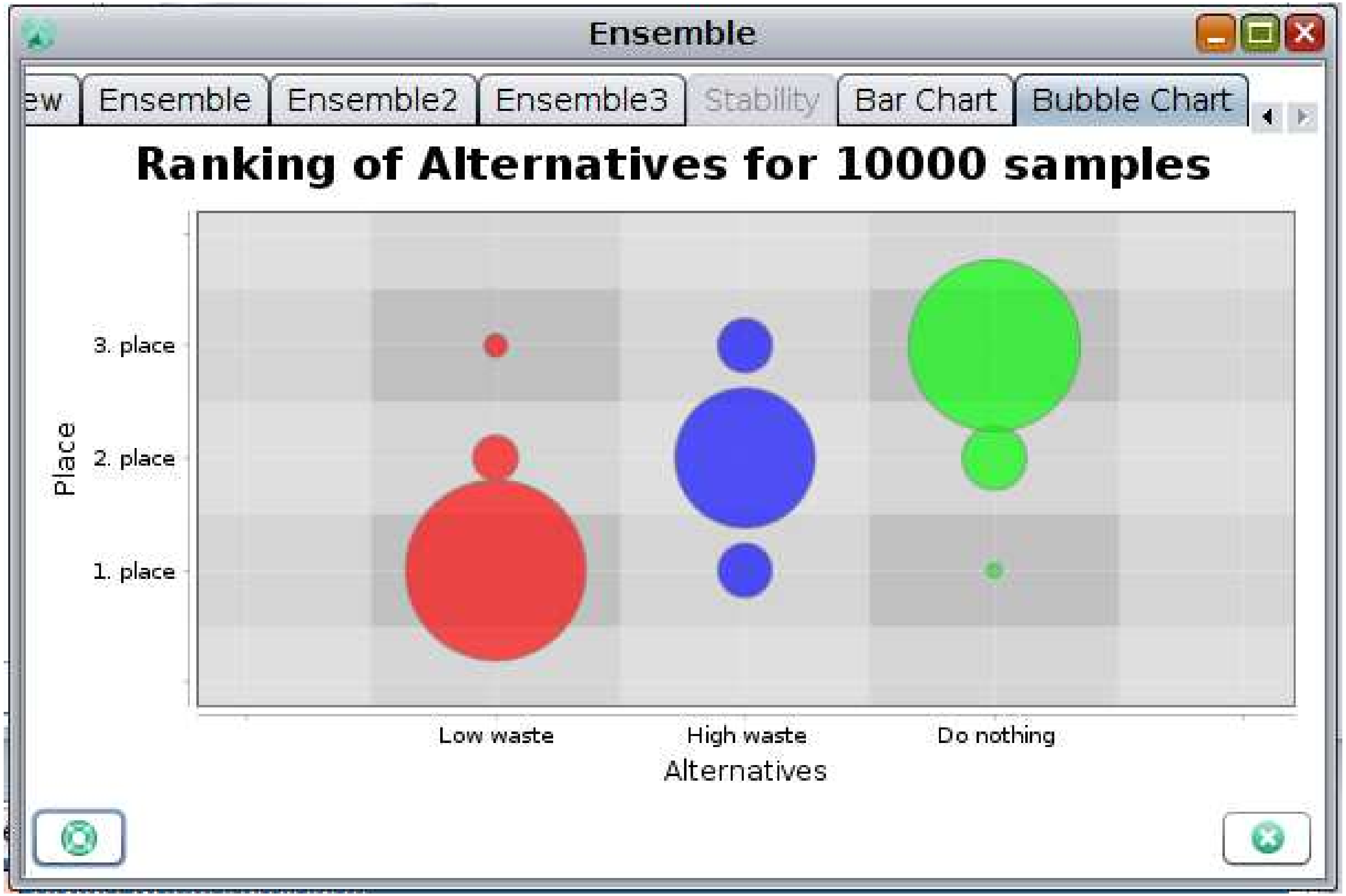
Uncertainties in result presentation



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How to proceed further

- There is a need to test this with technical teams and stakeholders
- Use of such visualisation in panels and exercises would be highly valuable
- Feedback from workshops in Slovakia (has been done) and Norway (Italy) can be used for feedback
- Feedback from this workshop is highly appreciated

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Thank you very much for your attention

Questions?

https://portal.iket.kit.edu/CONFIDENCE/

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