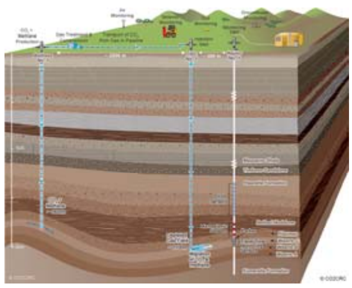
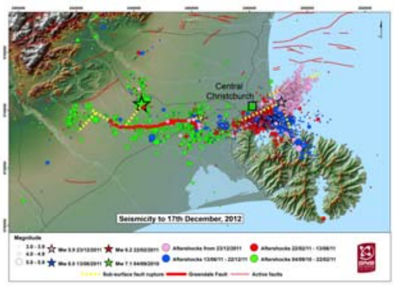
Expert elicitation in natural hazard and risk assessment in New Zealand

Annemarie Christophersen, Matt Gerstenberger, Rob Buxton, Natalia Deligne, Sally Potter, Lauriane Chadot

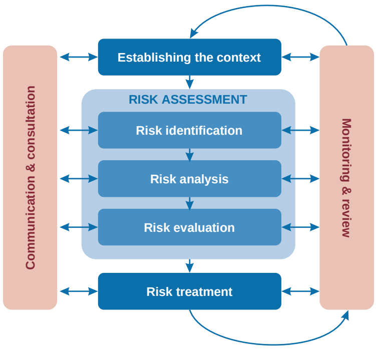
Outline

- Background: Risk assessment for carbon capture and storage (CCS)
- The Canterbury earthquake sequence
- Exploring the application of BBNs to volcanic hazard and risk





Risk assessment in CCS

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Integrated Risk Assessment for CCS

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Abstract

Currently there is no standard for risk assessment tools in Carbon Capture and Storage. Existing projects use a range of tools from the very simple to the sophisticated and probabilistic. It is likely that no standard will ever be appropriate for all uses and all stakeholders within CCS. A key component of risk assessment is to effectively communicate to stakeholders whether the risks have been thoroughly investigated and any potential risk is well understood. Using a suite of risk assessment tools across the lifecycle of a project will provide the best estimates of the risk and enable communicating this knowledge in the most effective manner. A key component in designing a risk assessment protocol is in selecting an expert elicitation method that is appropriate for the level of detail required by the tool. By using a structured elicitation to match the detail of the risk assessment tool, the best possible estimate of the risk will be obtained. Finally, we recommend a staged suite of risk assessment tools including brainstorming, bow tie diagrams, risk registers and Bayesian Belief Networks.

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IN; expert elicitation; Risk assessment guidelines

CO2CRC

Primer on Baysian Belief Networks BBNs

Showers on Sunday	
Yes 70%	
No 30%	

Conditional Probability Table

CPT

Yes	70%
No	30%

Adding evidence

Event A:

Showers on Sunday	
Yes 91%	
No 9%	

Showers on Monday	
Yes 70%	
No 30%	

CPT

Showers on Sunday	Yes	No
Yes	91%	20%
No	9%	80%

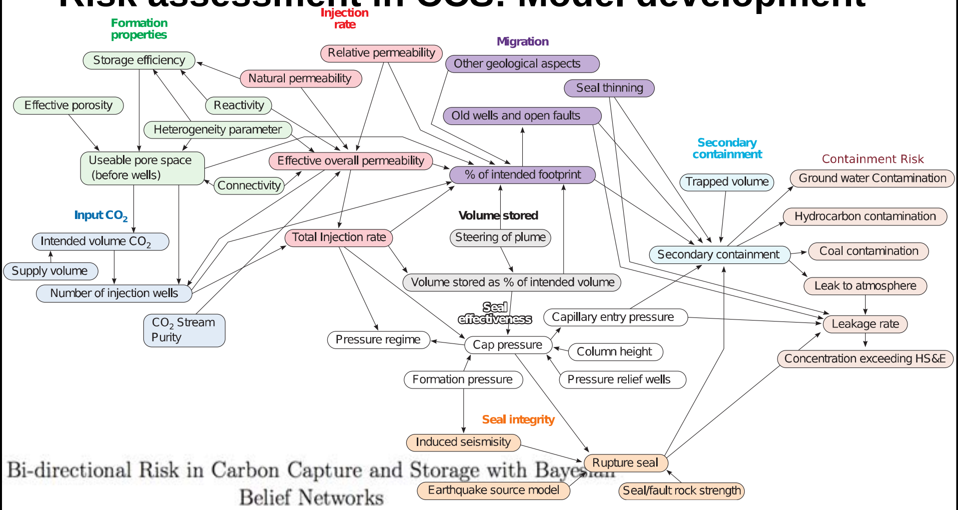
Event B:

Showers on Monday	
Yes 100%	
No 0%	

$$P(B) = P(A) * P(B) + P(A') * P(B)$$
$$= 0.7 * 0.7 + 0.3 * 0.7 = 0.70$$

$$P(A|B) = P(B|A)P(A)/P(B)$$
$$P(A|B) = 0.91 * 0.70 / 0.70 = 0.91$$

Risk assessment in CCS: Model development



Bi-directional Risk in Carbon Capture and Storage with Bayesian Belief Networks

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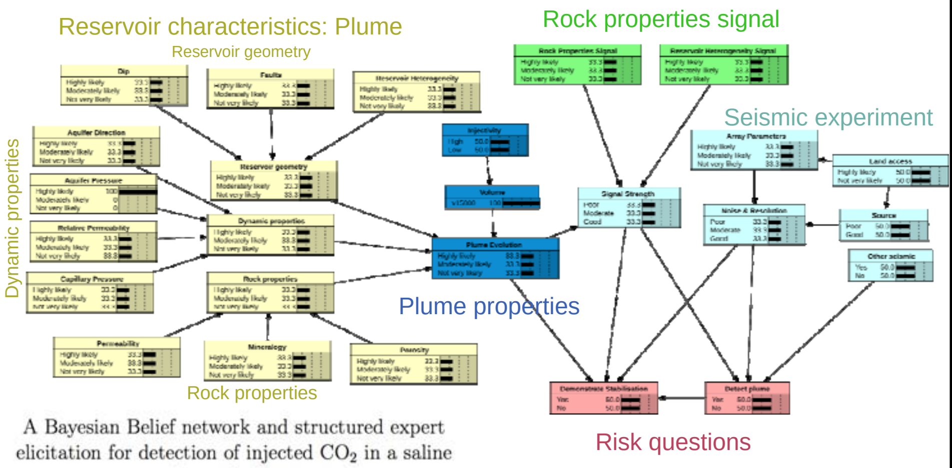
Detecting CO_2 plume with 4D seismic experiment



A Bayesian Belief network and structured expert elicitation for detection of injected CO_2 in a saline aquifer with 4D seismic

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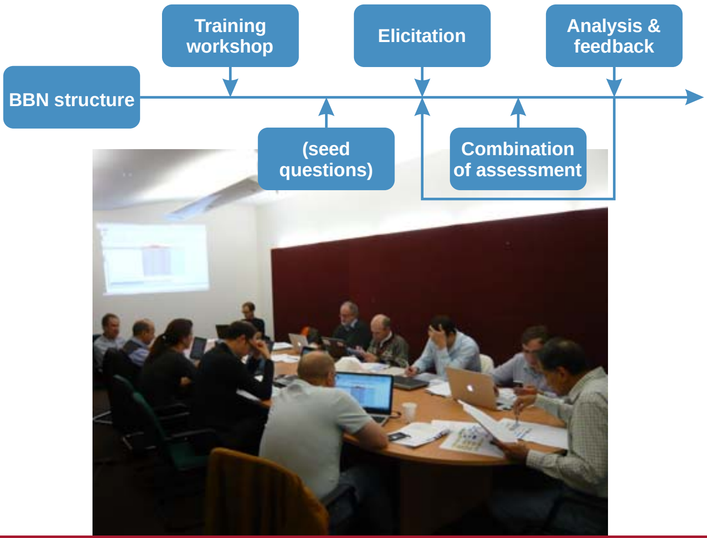
[a] GNS Science, Lower Hutt, New Zealand
[b] Cooperative Research Center for Greenhouse Gas Technologies, Canberra, Australia

Detecting CO_2 plume with 4D seismic experiment



Risk assessment in CCS: Structured expert elicitation

- Non-consensus process to capture the full range of uncertainty
- Prior to elicitation, each expert responded to 10 **seed questions**
- In the true elicitation, a **weight** was given to the **input of each expert** based on seed question responses

Seed Questions

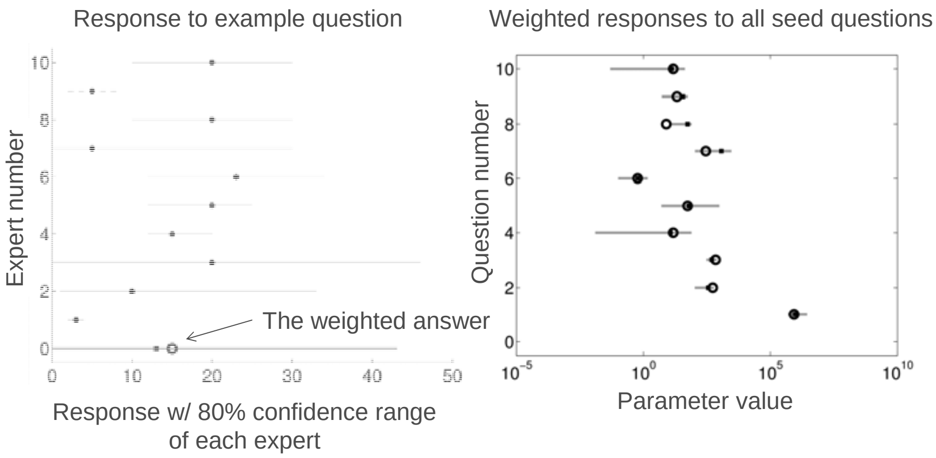
For expert elicitation in CCS

Christophersen, A., Arnot, M., Gerstenberger, M.C., and Nicol, A.

July 2013

CO2CRC Report No: RPT13-4375

Risk assessment in CCS: Evaluating the seed questions

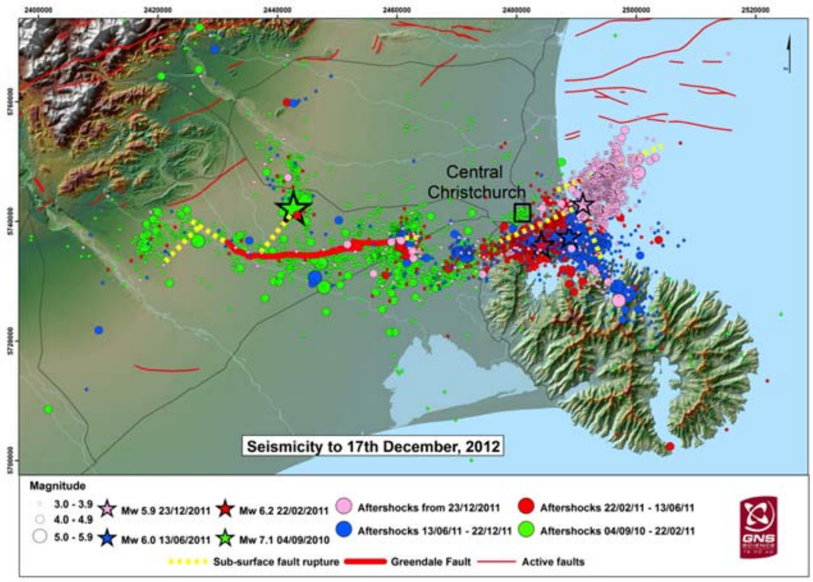


Risk assessment in CCS: Key points

- Research project, working mostly with the scientists from within the CO2CRC project.
- Model development team was subset of model quantification team.
- Initial reluctance, both to BBN as well as structured expert elicitation.
- Positive feedback afterwards.
- Deriving suitable calibration question was research project in itself!
- Outcomes now part of the Otway risk register and follow-up reservoir modelling undertaken.

Structured Expert Elicitation for a Time-Dependent Update of the New Zealand National Seismic Hazard Model for Canterbury

The Canterbury earthquake sequence

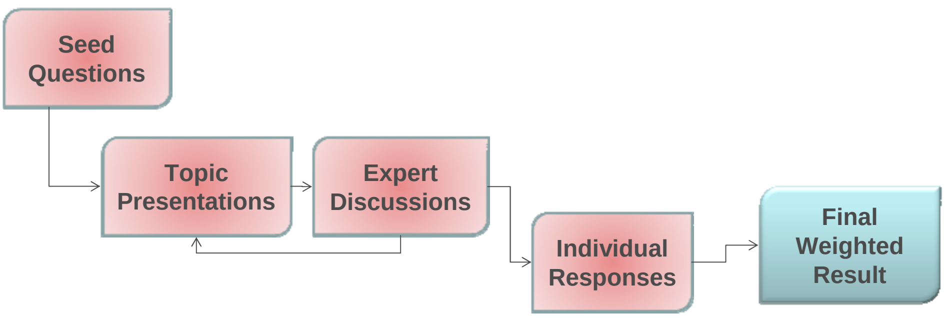


Model development

Use existing science and models already applied to New Zealand data to estimate the seismic hazard in the Canterbury region, for the next 50 years.

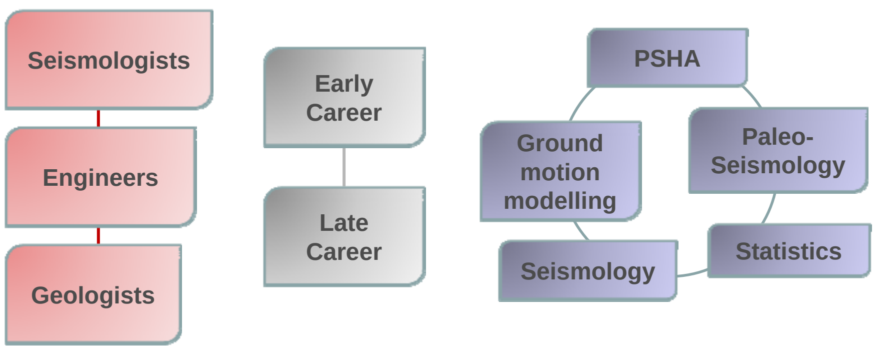
Expert elicitation

- Workshop 1: 3 days, 12 Experts & 50 target questions covering source models to GMPEs
- Workshop 2: 1 day, 5 experts & 12 target questions on GMPEs



The Experts

- Topics: Elicitation covered a wide range of topics from geology, seismology, statistical seismology, PSHA, ground motion prediction
- Experts: covering a similar & broad range of expertise, experience and point in career



Key points

- **Expert uncertainties**: A key goal is to understand how well each expert estimates the uncertainties in their own knowledge.
- **Within your bounds**: Getting the answer exactly correct is not the overriding goal
- **Thought process** is important:
  - To begin, establish what is known, no matter how big the limits; understand these limits.
- **Training Process**: Seed questions help to set the scene and establish thought processes for answering the target questions.

Model use and outlook

- Informing rebuilt of Christchurch.
- Setting building code standards.
- Use similar method to up-date seismic hazard model for all of New Zealand.
- Project ‘Rethinking Probabilistic Seismic Hazard Assessment’.

Gerstenberger, M.C.; McVerry, G.; Rhoades, D.A.; Stirling, M. 2014.
Seismic Hazard Modelling for the Recovery of Christchurch, New Zealand.
Earthquake Spectra, 30(1): 17-29, doi: 10.1193/021913EQS037M

White Island BBN project aim/ motiviation

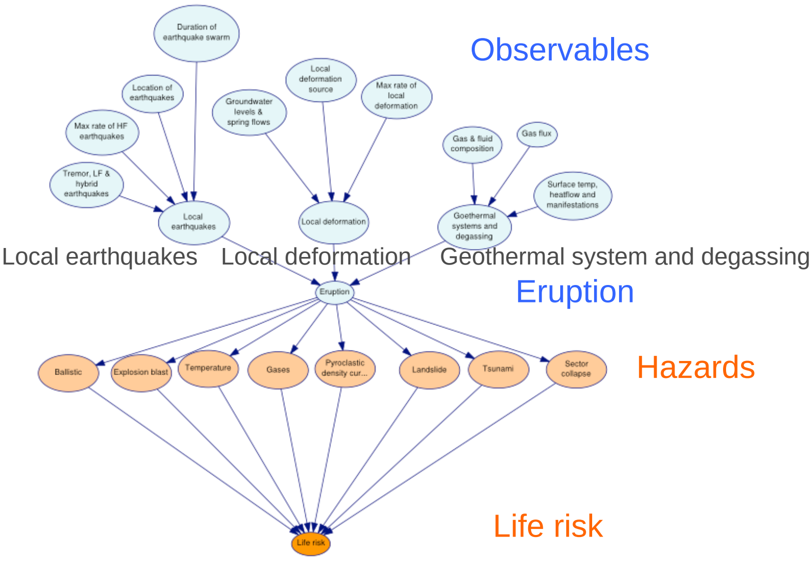
- Apply the tools and methods that we learned so much about, particularly during the CO2CRC work to other areas.
- Contribute our methods of risk assessment to the life-risk question for visiting volcanoes.

White Island BBN project background

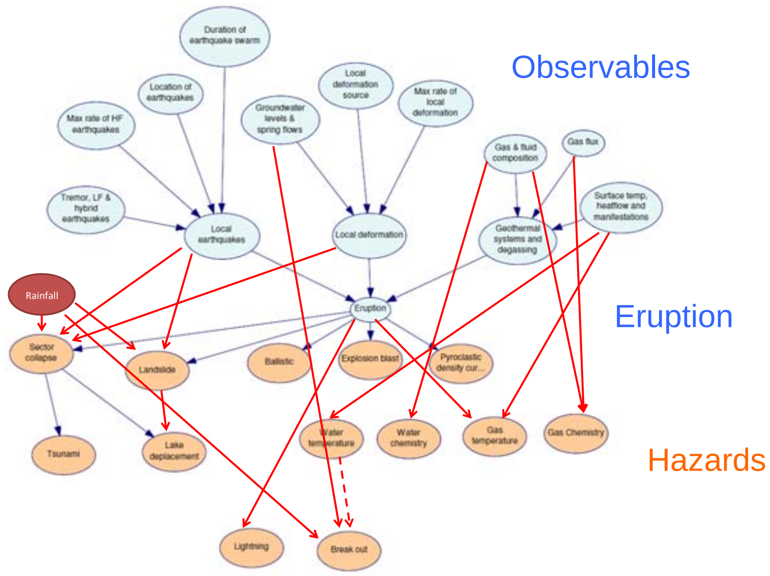
- Volcanic unrest since August 2012
- Limited access for volcanologists due to life safety risks
- Annualised risk of dying
  - $>10^{-3}$ no access
  - 10^{-4} short access
  - 10^{-5} longer access
  - 10^{-6} unlimited

- Volcanic monitoring team at GNS Science to analyse data and provide geological advice to government agencies
- Regular eruption probability estimate; converted to annualised risk of dying

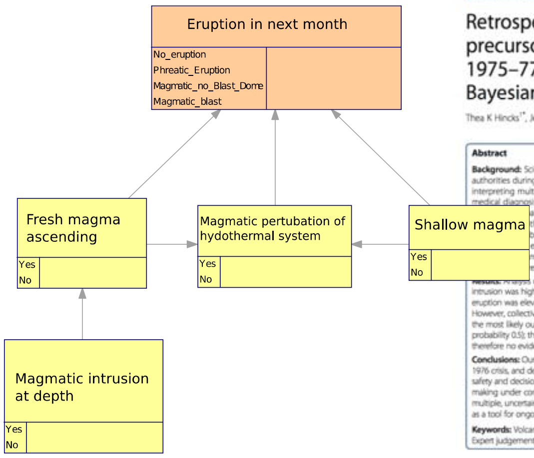
White Island: Model development

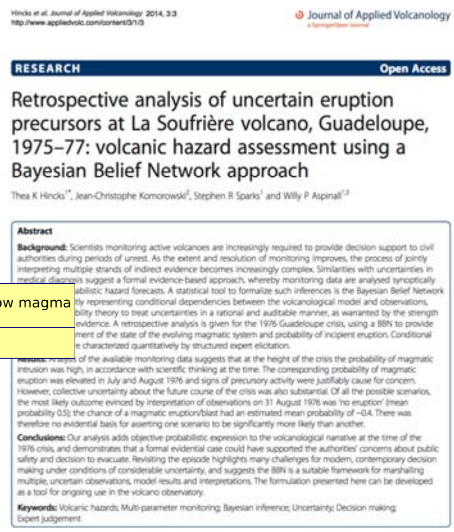


White Island: Model development



White Island: Model development





Hincks et al. Journal of Applied Volcanology 2014, 3:3
http://www.appliedvolc.com/content/3/1/3

Journal of Applied Volcanology

RESEARCH Open Access

Retrospective analysis of uncertain eruption precursors at La Soufrière volcano, Guadeloupe, 1975–77: volcanic hazard assessment using a Bayesian Belief Network approach

Thea K Hincks[1*], Jean-Christophe Komorowski[2], Stephen R Sparks[1] and Willy P Aspinall[1,3]

Abstract

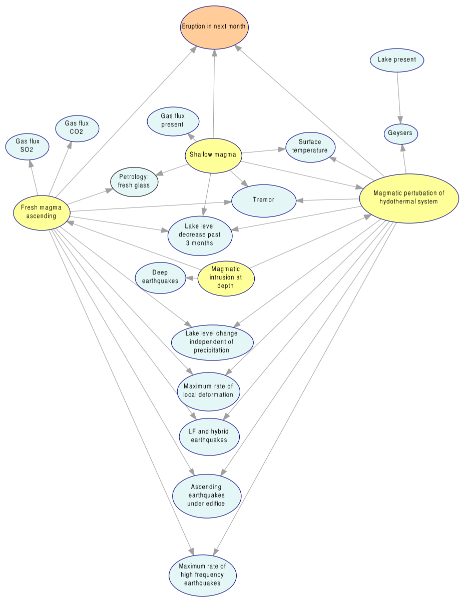
Background: Scientists monitoring active volcanoes are increasingly required to provide decision support to civil authorities during periods of unrest. As the extent and resolution of monitoring improves, the process of jointly interpreting multiple strands of indirect evidence becomes increasingly complex. Similarities with uncertainties in medical diagnosis suggest a formal evidence-based approach, whereby monitoring data are analysed synoptically ... abilistic hazard forecasts. A statistical tool to formalize such inferences is the Bayesian Belief Network ... tly representing conditional dependencies between the volcanological model and observations, ... bility theory to treat uncertainties in a rational and auditable manner, as warranted by the strength ... evidence. A retrospective analysis is given for the 1976 Guadeloupe crisis, using a BBN to provide ... ment of the state of the evolving magmatic system and probability of incipient eruption. Conditional ... e characterized quantitatively by structured expert elicitation.

Results: ... of the available monitoring data suggests that at the height of the crisis the probability of magmatic intrusion was high, in accordance with scientific thinking at the time. The corresponding probability of magmatic eruption was elevated in July and August 1976 and signs of precursory activity were justifiably cause for concern. However, collective uncertainty about the future course of the crisis was also substantial. Of all the possible scenarios, the most likely outcome evinced by interpretation of observations on 31 August 1976 was 'no eruption' (mean probability 0.5); the chance of a magmatic eruption/blast had an estimated mean probability of ~0.4. There was therefore no evidential basis for asserting one scenario to be significantly more likely than another.

Conclusions: Our analysis adds objective probabilistic expression to the volcanological narrative at the time of the 1976 crisis, and demonstrates that a formal evidential case could have supported the authorities' concerns about public safety and decision to evacuate. Revisiting the episode highlights many challenges for modern, contemporary decision making under conditions of considerable uncertainty, and suggests the BBN is a suitable framework for marshalling multiple, uncertain observations, model results and interpretations. The formulation presented here can be developed as a tool for ongoing use in the volcano observatory.

Keywords: Volcanic hazards; Multi-parameter monitoring; Bayesian inference; Uncertainty; Decision making; Expert judgement

White Island: Model development



Outlook

- ➢ Expert elicitation White Island in the near future to quantify BBN.
- ➢ Intended as decision support tool as well as a prototype.
- ➢ Framework applicable to other volcanoes and also modelling physical processes.
- ➢ Unsure about calibration questions yet.

Our challenges

- How to conduct unbiased and defensible model development?
- How to develop appropriate calibration questions?
- How to ease the elicitation burden, especially for BBNs?