Corps Risk Analysis Gateway Training Module

Expert Elicitation

Series:
Corps Risk Analysis Online Training Modules

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Contents

Expert Elicitation

This module was originally developed as a web-based training on the Corps Risk Analysis Gateway. The content has been modified to fit this format. Additional modules are available for download on the IWR website.

The purpose of this training module is to acquaint you with the expert elicitation process, one of the more useful methodologies for addressing critical uncertainty in decision-making.

After completing this module, you will be able to:

- Define expert elicitation
- Determine when it is appropriate to conduct an expert elicitation
- Discuss what constitutes an expert
- Identify the basic approaches to expert elicitation
- Recognize the elements of an expert elicitation
- Distinguish among the heuristic biases that challenge the elicitation process

The next two chapters provide an introduction to expert elicitation and a simple example of an elicitation that provides a more vivid background for understanding subsequent topics. Then uncertainty, which triggers the need for an elicitation process, is introduced and this is followed by a discussion of situations that could warrant an expert elicitation.

Following this background on the process, the focus shifts to the "expert" part of expert elicitation. The nature of expertise is taken up first, followed by an examination of the various roles required for a good expert elicitation. One of these roles, that of the expert, is developed and methods for identifying experts are considered.

The course then turns to the practical preparation for an elicitation. This includes structuring the problem, training the experts, and deciding on the type of elicitation to be conducted. This is followed by a description of the elicitation, which produces the raw information for the process. The course describes general strategies for combining the results from many experts. This synthesis of data evolves into a description of how the elicitation results may be used.

An expert elicitation protocol is presented to pull the preceding information together into a coherent whole; a few alternative protocols are also summarized.

Finally, several heuristics and biases, well known to challenge the expert elicitation process, are identified[1].

The course concludes with a summary, a list of references and other resources, and the course assessment.

You are encouraged to read through all of the examples provided in this module, which look at specific concepts in more depth.

This training is approximately one and a half hours.

This course includes a self-assessment; it's recommended that you be able to achieve 70% for successful course completion.

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[1] A heuristic is a mental shortcut that speeds up the decision making process. They include practical approaches that are not always accurate.

Chapter 1 - Introduction to Expert Elicitation

1.0 Introduction to Expert Elicitation

The USACE Civil Works Program is beset with uncertainty. Much of it can be reduced by data collection, analysis, research, or professional judgment. Some uncertainty is persistent, however, and it has the potential to affect project outcomes and decision making. Examples may include such things as:

- How do you quantify the probability that a levee will fail to function as designed?
- How do you estimate savings to operation and maintenance that will result from implementing a new technology?
- How do you handle the effects of climate change on a project's performance when it will take decades before the first data become available?
- How do you describe the impacts of a wider navigation channel on the number of marine casualties?
- How do you predict the size of an oil spill to evaluate its environmental consequences?

If you have holes like these in your data that you cannot fill by any other means, an expert elicitation may be your best option for quantifying the uncertainty and allowing you to proceed. Lack of data is the starting point for an expert elicitation.

An elicitation consists of three parts — **preparation, elicitation, and synthesis** — as seen below:

Figure 1. An elicitation consists of three parts.

Elicitations can vary in their rigor. A visit to a colleague's cubicle requires little preparation; simple conversation may elicit the required information, and synthesis may be as simple as plugging a value into a spreadsheet calculation. Other situations call for a more formal process.

Expert elicitation is a formal and systematic process for obtaining and quantifying expert judgment in order to characterize the uncertainty about decision critical quantities. It does not create new knowledge; instead, it characterizes the state of knowledge about some issue or quantity that is uncertain. Expert elicitation is confined to science and matters of fact; it does not consider social values or preferences since other tools are available to address those topics.

When the value of a quantity is not known by anyone, the judgments, knowledge and experience of experts in the relevant field of inquiry are our most valuable assets. It is important to understand that even an expert will be uncertain about the true value of the quantity. Ideally, experts will have more information, making them less uncertain than most, or they at least have a better understanding of the extent of the uncertainty. Expert elicitation is a process to frame the uncertainty about a value; it is not a way of determining the uncertain variable or parameter value. Consequently, expert elicitation does not provide point estimates of uncertain quantities or create new knowledge. It uses available knowledge and opinion to characterize what an uncertain variable or parameter might be.

Expert elicitation is not an alternative to doing the needed science or data collection when it is reasonably available. The information derived from an elicitation is not the same as data obtained from empirical studies. Expert elicitation data provide a measure of uncertainty where the uncertainty is due to knowledge uncertainty. By contrast, data from well-designed empirical studies provide a measure of certainty.[2]

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[2] Australian Centre of Excellence for Risk Analysis (ACERA). 2010.

Chapter 2 - Expert Elicitation Example

2.0 Expert Elicitation Example

Most people have never participated in an expert elicitation and are unlikely to know what it is, why it is done, or how it is done. To facilitate that understanding, let us introduce a simple example we can refer to periodically, beginning here, to illustrate the concepts discussed in this module. A video demonstrating this example is found in Chapter 12.

Imagine a local port authority in partnership with the U.S. Army Corps of Engineers (USACE) is considering expanding its oil handling capacity in a harbor. The project delivery team (PDT) is considering changes to the depth and width of existing navigation channels. One of the potential risks of greatest concern is the effect of an oil spill on the environment. An initial consideration of this risk has identified the size of the oil spill as a significant uncertainty. Now, suppose the PDT has decided to characterize this uncertainty using an expert elicitation. This oil spill example will be referred to at times to illustrate ideas presented in the sections that follow. Let us begin with the concept of uncertainty.

Chapter 3 - Uncertainty

3.0 Uncertainty

Reducing uncertainty is the only reason for conducting an expert elicitation. An elicitation is triggered by the existence of an uncertain value that is critical to our decision problem. That value in our example is the size of a potential future oil spill or spills.

When you are not sure, you are uncertain. USACE employees in every part of the organization—programs, planning, project management, construction, operations, regulatory, real estate, contracting, counsel, public affairs, and so on—face uncertainty on a regular basis. Uncertainty is so common we often do not even notice its presence. We have all become quite adept at handling the routine uncertainties of our days from the natural variability in our wake-up time, our commute, the length of meetings, and the quality of our food to the routine knowledge uncertainty we constantly reduce and extinguish through conversations, internet searches, information sources, research, and analysis.

Much of the day-to-day work of the USACE is devoted to reducing routine uncertainties, yet some uncertainties are amazingly persistent and resist our best efforts to reduce them. Lack of data has already been identified as one of the chronic causes of uncertainty. Another cause of uncertainty is the fundamentally unknowable nature of some facts, like the outcome of events in the future. When it comes to decision-making, some uncertainties are trivial, e.g., the cost of nails will not matter much in the major rehabilitation of a levee; others are critical to the success of a decision, e.g., what are the foundation conditions beneath that levee?

Significant uncertainties, i.e., those that can affect the decision made or the outcome of a decision, cannot be ignored. Gathering information by any means necessary is the simplest fundamental strategy for reducing uncertainty, but sometimes gathering additional information is not possible. The manifestations of climate change will not be known for many decades, future geo-political conditions are unpredictable, the outcomes of risk management measures never before implemented will not be revealed in time to assist planners and project managers, and it can take a long time to accumulate some kinds of data. In other cases, data are too difficult or expensive to collect. Some significant uncertainties are always going to remain in a program as diverse and complex as the USACE Civil Works Program. What can be done in these cases?

It is a rare instance when the collective wisdom of our societies can say nothing at all about an uncertain scenario, situation, event, variable, or quantity. Expert elicitation is an information gathering technique designed to tap the knowledge of experts in an effort to characterize uncertainties that cannot be practically reduced any other way. It is important to understand from the outset that expert elicitation does not “fill” a data gap; instead, it characterizes the nature of the gap itself.

An expert elicitation begins by identifying the uncertain variables to be assessed. This is a primary responsibility of the sponsor for an expert elicitation. They must identify the quantities to be elicited as well as any questions to be answered by an expert elicitation. For simplicity, our example has only one variable of interest, the size of a potential future oil spill, given that a spill occurs. It is more likely there will be several variables to assess in an expert elicitation, but we want to keep our example simple.

Check your understanding with this brief quiz.

EXPLORE: EXPERT ELICITATION

Check your understanding of the concepts of expert elicitation with this brief quiz:

Check Your Knowledge: Expert Elicitation

It's time to check your knowledge on expert elicitation. Let's see how you're doing with a few important concepts.

1. Expert elicitation can be a reasonable alternative to collecting the available data. True or false?

2. Expert elicitation fills gaps in data with new knowledge. True or false?

3. When an analyst decides how to quantify uncertain values this is a simple example of a formal elicitation. True or false?

Check Your Knowledge: Expert Elicitation - ANSWERS

1. Expert elicitation can be a reasonable alternative to collecting the available data. True or false?

FALSE. It is never to be used as a short cut when data are reasonably available.

2. Expert elicitation fills gaps in data with new knowledge. True or false?

FALSE. Expert elicitation does not create knowledge, it characterizes the state of knowledge about an uncertain quantity.

3. When an analyst decides how to quantify uncertain values this is a simple example of a formal elicitation. True or false?

FALSE. This is actually an example of a fairly common form of informal elicitation used by USACE.

Chapter 4 - Expert Elicitation Situations

4.0 Expert Elicitation Situations

Data can be considered to be useful information in all of its forms and we lack data for our oil spill example. Imagine that there has never been an oil spill in our hypothetical harbor. Bear in mind the oil handling capability will be an unprecedented size for this harbor. "With condition" data in planning studies is almost always uncertain. In this instance we are concerned about the size of an oil spill that may or may not ever occur in the future, but if it does it will be under conditions that have never existed before. This is a good example of a situation that warrants an expert elicitation.

There are many reasons for conducting an expert elicitation. Data, credibility, decision and other reasons for an expert elicitation are summarized in the sections that follow.

Data Reasons for an Expert Elicitation

- Data have never been collected.
- Data can never be collected.
- Data will not be available for a long time.
- Your data are sparse and need to be interpolated or extrapolated.
- Your data are outdated.
- The provenance and quality of your data are unknown.
- The available data are conflicting.
- To help interpret observed data.
- You deal with situations that have never existed before.
- Uncertainties are large and significant.
- There is a clearly critical uncertain variable (or more) in your risk assessment model.
- Analyses are not practical to perform.
- The available data are consistent with and can be explained by more than one conceptual model (for instance, perhaps the data is consistent with both a growing population model and a declining population model).

Credibility Reasons for an Expert Elicitation

- Your issue is a controversial one.
- Your problem is complex and highly visible.
- Your issue is subject to intense media or other scrutiny.
- There are values in conflict for your issue.
- There are many stakeholders with diverse views.
- Trust in your analytical work is an issue.
- One or more stakeholders are likely to challenge your decision in a court or administrative setting.

Decision Reasons for an Expert Elicitation

- Your organization has stewardship responsibility for some public value, e.g., public health, public safety, water resources, homeland security, etc.
- Human life, health, or safety may be affected by your decision.
- Your risk assessment will provide the basis for public decision-making.
- Your risk assessment will provide the basis for a formal rule or regulation affecting industry, non-governmental organizations, or others.
- To forecast the effectiveness of risk management options.

Other Reasons for an Expert Elicitation

- To promote consensus among experts regarding a complex decision.
- To provide input for the prioritization of research options.
- Technical judgments are required to assess whether bounding assumptions or calculations are appropriate.
- To provide quantitative bounds on subjective judgments.
- To interpret qualitative terms, e.g., “likely” and “rare.”
- To obtain prior distributions for Bayesian statistical models.

EXPLORE: TENKILLER

Deciding that you need an expert elicitation is an important threshold decision to make as a preparation task. To help clarify the conditions warranting an expert elicitation, let us consider uncertainties that do not warrant an expert elicitation. This example presents two examples of uncertainties that can be handled through the available sparse data and the expert judgments of those responsible for the analysis. (A video is available.)

In this video, we will look at an ecosystem restoration analysis for Tenkiller Ferry Lake in Oklahoma. As part of the evaluation of an ecosystem restoration project downstream of Tenkiller Dam in Oklahoma our team developed habitat evaluation procedure (HEP) models (US Fish and Wildlife Service, 1980) for catfish, bass and trout. The model output, the change in habitat units attributable to the addition of a small weir dam downstream of the outlet structure and shown here was only one of the decision criteria for this project.

The model consists of hundreds of variables about which there was uncertainty, either natural variability, knowledge uncertainty or both. You do not need a formal elicitation process for every uncertain quantity you encounter in a risk assessment or decision problem. Usually, most uncertain quantities encountered in USACE work will be described using uniform, triangular, PERT or other nonparametric distributions for which the assessors estimate the defining values. Such uncertainties occur routinely and they are treated routinely.

Most variables in the HEP models were described by minimum, most likely and maximum estimates provided by two local resource agency employees. There was no formal elicitation process. They were more than competent to answer questions like, “What is the minimum water temperature in this stretch of the river during the summer months?” You also can see the distributions used for the percent of pools in the river, growing season, and the like. In addition, the HEP models were not terribly sensitive to minor changes in the input variables and the budget for the analysis was about $14,000 in a multi-million dollar project. There was no option for obtaining better data.

You do not need to complete a formal elicitation process for every uncertain variable in your decision problems.

EXPLORE: EXPERT ELICITATION ITEMS

Not every persistent uncertainty requires an expert elicitation. As the reasons for an elicitation, described in the previous sections, begin to accumulate so does the importance of the decision and the need for a more formal and credible process for estimating probabilities and uncertain values in our models and decision processes.

Check your understanding with this short quiz:

Check Your Knowledge: Expert Elicitation Items

It's time to check your knowledge on some expert elicitation items. Which of these uncertainties have a part in expert elicitation and which do not?

1. Total budget levels for USACE in the next fiscal year

2. Describing how normalization of trade with Cuba would affect Ports in Miami and Fort Lauderdale

3. The number of utilities that cross a stream channel in a city

4. Foundation conditions for a new levee alignment

5. Probability that fracking could cause an earthquake that would affect a USACE dam

6. Estimating cargo tonnage that would move through various Arctic Marine Shipping scenarios

Check Your Knowledge: Expert Elicitation Items - ANSWERS

1. Total budget levels for USACE in the next fiscal year

Expert Elicitation is not needed

2. Describing how normalization of trade with Cuba would affect Ports in Miami and Fort Lauderdale

Expert Elicitation may be appropriate

3. The number of utilities that cross a stream channel in a city

Expert Elicitation is not needed

4. Foundation conditions for a new levee alignment

Expert Elicitation is not needed

5. Probability that fracking could cause an earthquake that would affect a USACE dam

Expert Elicitation may be appropriate

6. Estimating cargo tonnage that would move through various Arctic Marine Shipping scenarios

Expert Elicitation may be appropriate

Chapter 5 - Expertise

5.0 Expertise

Identifying and convening the expert panel is a critical part of the expert elicitation preparation process. To consider how this is done, let us first consider what we mean by expertise. Expertise runs a continuum from the layman, with no special knowledge of or experience in the subject matter domain (in this case, oil spills), to the novice, just beginning to acquire skills in the relevant field, to the journeyman whose knowledge and skills have not yet peaked, to the grand master who is not likely to learn a great deal more. USACE will sometimes need experts (i.e., from the grand master end of the continuum); or sometimes a novice, fresh out of school and familiar with the latest methods, will be just what is needed.[3]

Figure 2. Spectrum of Expertise.

There are a number of indicators that are helpful to distinguish level of expertise. There are some good ones and some not so good ones. You can review them in the sections below.

"Good" indicators of expertise

- Formal education in relevant domains
- Professional experience, including on-the-job, research, and consulting
  - Amount, e.g., years of experience
  - Types of experience
  - Quality of experience (e.g., practical vs. academic)
- Demonstrated experience with related problems
- Publication record in relevant domains
  - Peer reviewed publications
  - Other publications
  - Talks and presentations of note
- Evidence of ability to communicate
- Membership and leadership positions in professional societies
- Awards and other indications of peer recognition
- References from other experts

- Accuracy of past judgment
- Prior participation in expert elicitations

"Poor" indicators of expertise

- Job title/social role
- Confidence
- Verbosity and prolific publications
- Media presence

The continuum of expertise covers several different kinds of knowledge as indicated below. Elicitation sponsors must identify the kinds of knowledge they require to address a particular problem.

- Procedural knowledge is about how to do things, e.g., running specialized software such as the Institute for Water Resources' (IWR) Planning Suite, decision support software.
- Declarative knowledge is about the facts and the rules of a knowledge domain, e.g. how oil transfers occur at port facilities.
- Theoretical knowledge concerns general principles, e.g., a statistician has theoretical knowledge.
- Practical knowledge focuses on how to apply the principles in specific cases, e.g., an actuary has practical knowledge.
- Normative knowledge includes the formal and abstract methods for expressing domain knowledge, e.g., an expert in the design and conduct of expert elicitations.
- Substantive knowledge of the relevant domains includes knowledge of the real factors that influence domain knowledge, e.g., people who are experts in the unknown quantity.

For our oil spill problem, we are likely to need theoretical knowledge about the transport and fate of spills, normative knowledge of the oil industry, and substantive knowledge of oil spills. Other forms of knowledge are more *nice-to-have* than *must-have* knowledge for our example.

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[3] Adapted from European Food Safety Authority (EFSA) 2014.

Chapter 6 - Roles

6.0 Roles

We can distinguish at least seven distinct roles in an expert elicitation. These roles are distinguished by the type of knowledge held and/or function that would be performed. They are sponsor, facilitator, domain expert, trainer, elicitor, panel expert, and analyst. One person may play multiple roles, but each of the roles is indispensable. The expert panel members, however, should play only the role of panel expert. It would not be unusual for the facilitator, trainer, and elicitor roles to be played by the same person. When the desired skill set cannot be filled by a single person, two or more people may play these roles. The basic functions of each role are listed on the sections below.[4]

Sponsors

- Define the decision problem
- Help prepare the agenda
- Help define the elicitation protocol
- Provide resources for elicitation
- Procure services of other expert elicitation team members

Facilitators

- Help prepare the agenda
- Help define the elicitation protocol
- Work effectively with the group to produce a shared outcome
- Lead the expert elicitation process

Domain Experts

- Help frame decision problem for expert panel
- Interpret context, background information, and the meaning of questions
- Serve as technical resource to expert panel prior to and during elicitation
- Do not participate as expert in the elicitation

Trainers

- Conduct calibration exercises
- Instruct expert panel in ways of minimizing biases
- Instruct expert panel in ways of estimating subjective probability distributions

Elicitors

- Assist in training in eliciting subjective probability distributions
- Challenge misconceptions
- Keep individual experts focused on characterizing uncertainty about “X” and not providing a point estimate of “X”
- Conduct the elicitation

Panel Experts

- Clarify the decision problem and questions to be answered
- Learn to characterize uncertainty in the required manner
- Provide subject matter expertise
- Work within group as required to develop consensus

Analysts

- Synthesize the final elicitation data
- Assure data are used appropriately in subsequent analyses

Sponsors provide the reason, rationale, and resources required for an expert elicitation. The facilitator tailors her style to the needs of the expert elicitation sponsors and the members of the expert panel in order to ensure the smooth conduct of the elicitation. Domain experts are recognized and respected authorities within their domain of expertise but are not members of the expert panel. They are resources to the panel. The trainer’s role may be filled by the facilitator. When it is not, a trainer will be needed to help the expert panel members express subjective probability and other estimates in an unbiased fashion. An elicitor may be needed if the trainer and facilitator are not qualified to fill that role. The elicitor obtains the values used to characterize the uncertainty about a quantity. Experts may find the elicitation process difficult despite decades of subject matter experience because they have never had to make probabilistic judgments. One or more analysts will be required to synthesize and use the data.

EXPLORE: ROLES IN EXPERT ELICITATION

Check your understanding of the roles in an expert elicitation with this short quiz.

Check Your Knowledge: Roles in Expert Elicitation

It's time to check your knowledge on roles in expert elicitation. Roles in expert elicitation can include Sponsors, Facilitators, Trainers, Domain Experts, Elicitors, and Expert Panelists. Match a person's role to the activity they would perform during an expert elicitation.

Activity:

A) Serves as technical resource to expert panel during elicitation
B) Clarifies the decision problem and questions to be answered
C) Focuses on characterizing uncertainty about a value, not estimating it
D) Provides resources for elicitation
E) Helps expert panel minimize their biases
F) Defines the elicitation protocol

Roles:

- Sponsor
- Facilitator
- Trainer
- Domain Expert
- Elicitor
- Expert Panel

Check Your Knowledge: Roles in Expert Elicitation - ANSWERS

Activity:

A) Serves as technical resource to expert panel during elicitation
B) Clarifies the decision problem and questions to be answered
C) Focuses on characterizing uncertainty about a value, not estimating it
D) Provides resources for elicitation
E) Helps expert panel minimize their biases
F) Defines the elicitation protocol

Roles:

Sponsor

D) Provides resources for elicitation

Facilitator

F) Defines the elicitation protocol

Trainer

E) Helps expert panel minimize their biases

Domain Expert

A) Serves as technical resource to expert panel during elicitation

Elicitor

C) Focuses on characterizing uncertainty about a value, not estimating it

Expert Panel

B) Clarifies the decision problem and questions to be answered

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[4] ACERA. 2010; EFSA. 2014.

Chapter 7 - Categories of Experts

7.0 Categories of Experts

Closely related to these different roles and kinds of knowledge are three broad types of experts commonly involved in an expert elicitation; they are generalists, subject matter experts (SME), and normative experts.[5] Generalists are usually most helpful in decomposing the problem and identifying the key uncertainties. They will often be found among the USACE staff and they are most often resources to the panel. SMEs usually sit on the expert panels and provide the most valuable outputs in an expert elicitation. They may come from within or outside of the USACE. Normative experts usually conduct the expert elicitation and elicit the information needed. Thus, when you think of recruiting experts, think more broadly than just the experts who comprise your panel. Each expert type is described briefly on the sections below.

Generalists

Generalists usually have substantive knowledge in one of the problem relevant disciplines as well as a sound general understanding of the technical aspects of the problem. Criteria for the generalists in an elicitation include:

- The necessary knowledge and expertise
- Demonstrated ability to apply their knowledge and expertise
- A broad diversity of independent opinion and approaches to the topic
- Willingness to be publicly identified as a member of the panel
- Willingness to identify potential conflicts of interest

SMEs

SMEs are at the forefront of a specialty that is relevant to the decision problem. Generally, they are recognized by their peers as authorities because of their sustained and significant research or other involvement with the topic area. The criteria for SMEs include those of the generalist as well as:

- Flexible thought
- The ability to objectively consider evidence that challenges their views
- The ability to explain complex topics clearly

Normative Experts

Normative experts tend to have training in risk assessment, probability theory, psychology, and decision analysis. Their role is to help the generalists and SMEs to articulate their professional judgments.

EXPLORE: DIFFERENT EXPERTS

Check your understanding of experts and expertise with this short quiz.

Check Your Knowledge: Different Types of Experts

It's time to check your knowledge on the different kinds of experts in expert elicitation.

The different types of elicitation experts include generalists, subject matter experts, and normative experts. Different kinds of experts are needed. Let's see what you know about these experts and their different kinds of knowledge.

A. Match the expert to the description.

Descriptions:

A. At the forefront of a relevant specialty
B. Helpful in decomposing the problem and identifying the key uncertainties
C. Elicit the judgements sought

Experts:

- Normative experts
- Generalists
- SMEs

B. Match each type of knowledge to its description.

Descriptions:

A. Can apply Bayesian principles to a problem
B. Understands the hydroeconomic models used to calculate expected annual damages
C. Can run HEC FDA
D. Use probability theory to develop a fragility curve
E. Knowledge of the factors that can cause levee failure

Knowledge:

- Declarative knowledge
- Normative knowledge
- Substantive knowledge
- Procedural knowledge
- Theoretical knowledge

Check Your Knowledge: Different Types of Experts - ANSWERS

A. Match the expert to the description.

Descriptions:

A. At the forefront of a relevant specialty
B. Helpful in decomposing the problem and identifying the key uncertainties
C. Elicit the judgements sought

Experts:

- Normative experts
  C) Elicit the judgements sought
- Generalists
  B) Helpful in decomposing the problem and identifying the key uncertainties
- SMEs
  A) At the forefront of a relevant speciality

Match each type of knowledge to its description.

Descriptions:

A. Can apply Bayesian principles to a problem
B. Understands the hydroeconomic models used to calculate expected annual damages
C. Can run HEC FDA
D. Use probability theory to develop a fragility curve
E. Knowledge of the factors that can cause levee failure

Knowledge:

- Declarative knowledge
  B) Understands the hydroeconomic models used to calculate expected annual damages
- Normative knowledge
  D) Use probability theory to develop a fragility curve
- Substantive knowledge
  E) Knowledge of the factors that can cause levee failure
- Procedural knowledge
  C) Can run HEC FDA
- Theoretical knowledge
  A) Can apply Bayesian principles to a problem

[5] U.S. Environmental Protection Agency (EPA). 2011.

Chapter 8 - Identifying Experts

8.0 Identifying Experts

Once you understand the kinds of expertise and experts you require to characterize your uncertainty, it is time to develop an expert profile. This is done by identifying the essential and desirable expertise for your problem.

The expertise required for our oil spill example follows:

Essential expertise

- Substantive knowledge of the properties of different petroleum products
- Substantive knowledge of petroleum product handling in ports and aboard all kinds of vessels
- Substantive knowledge of conditions leading to oil spills
- Substantive knowledge of transport and fate of spills.

Desirable expertise

- Normative knowledge of expressing oil spills and oil spill impacts in standard metrics
- Declarative knowledge of the relevant USACE guidance
- Ability to quantify risk probabilistically.

Identifying Experts continued

Based on the profile, the following specific experts were consequently identified:

- Petroleum engineer
- Marine engineer
- Hydraulic engineer
- Hydrologist
- Toxicologist
- Emergency response engineer with oil spill experience
- Site engineer with experience within the harbor
- Academic with knowledge of relevant transport and fate models
- USACE operations and maintenance expert.

Using the lists of expertise and experts, your expert elicitation preparation task continues by creating an expert profile matrix. A partial profile is shown below. The experts become the columns of the matrix, and the expertise types become the rows of the expert profile matrix. Your next task is to fill the cells of this matrix with the names of expert panel candidates. Candidates for the panel who "fill" the most cells are the most qualified. Expect that some experts will fill more than one role and provide more than one kind of expertise. Most likely, you will have some cells that go unfilled; as long as they are not among the essential expertise categories, it is okay.

Expertise types	Petroleum engineer	Marine engineer	Hydrologist	Toxicologist
Knows petroleum products	Capt. Brown			
Product handling in port	Capt Brown	Mr. Green		
Oil spill conditions	Capt Brown	Mr. Green		
Transport and fate				Dr. Robinson
Oil spill impacts				Dr. Robinson
USACE guidance			Ms. Lough	
Quantify probabilistically				

Figure 3. Partial expert profile matrix.

Six to twelve experts on a panel is common. A minimum of six experts helps to assure the robustness of the results. However, the benefits of additional members diminish rapidly with participation of more than twelve people.

More expertise is not always preferred to less. If you cover the necessary expertise with six experts or so do not add experts just to have more. Structural change in the domain or institutional biases may be arguments for "newer experts" as opposed to grand masters. Make sure your experts represent all the major perspectives and interpretations of the existing information that exist within the relevant community of practice.

Figure 4. The U.S. Army Corps of Engineers hosted the High-level Experts Leaders Panel (HELP) on Water and Disasters in October 2014. While in D.C., the group also toured various sites connected to the history of USACE. (Photo by John Hoffman)

Finding good experts is not as easy as it would seem. Here are some suggestions for finding experts:

- Begin with a web search.
- Literature review- Who is publishing on the topics of interest?
- Check the H-Index for the relevant community of practice.[6]
- Look for experts who are representatives on relevant committees.
- Look for people with substantial, direct experience with the problem at hand, regardless of their formal qualifications.
- Put out a call for experts and let them self-identify.
- Check member directories of professional associations in the fields of interest.
- Ask relevant professional, industry, or other organizations to nominate experts.
- Hire a headhunter firm.
- Call someone in the relevant community of practice and ask for the names of experts.
- Ask a professor for names of leaders in the field.

Once you have identified candidate experts, it is time to contact them and provide them with a summary of the problem and a preliminary charge to the panel that describes their responsibilities.

[6] Based on the work of Hirsch 2005, H-index is a recognized measure of the number of citation counts for all published papers and ranked by the number of times cited. There are a number of on-line tools that calculate citation counts and an individual's h-index. See Scopus (http://www.elsevier.com/online-tools/scopus/features) or Web of Science (http://wokinfo.com/).

Chapter 9 - Structuring the Problem

9.0 STRUCTURING THE PROBLEM

Once your experts have been identified and assembled, the next preparation task is to structure the problem. The overarching goal of this task is to develop an unambiguous definition of the quantities to be assessed in a form meaningful to the experts. In our example, experts will be called upon to characterize the uncertainty about the size of potential oil spills in the improved harbor. This effort usually includes a formal and structured effort to share the best available data with all expert panel members. For our example, these data might include information on the number, frequency, and size of U.S. oil spills as well as a thorough description of the harbor, including any oil spill history and the planned improvements. These data would typically be provided to the experts prior to convening the panel.

Figure 5. The oil tanker Exxon Valdez ran aground on Bligh Reef in Prince William Sound on March 24, 1989 spilling nearly 11 million gallons of crude oil into the sound. The resulting oil slick spread west, with patches from the spill eventually sighted more than 300 miles from Bligh Reef. The Emergency Operations Center (EOC) mobilized by the Joint Task Force-Alaska collected and contained oil in circles of boom material nicknamed “doughnuts.” Oil and contaminated solids from the doughnuts were then pumped aboard two Portland District dredges and stored until it could be unloaded into barges. The dredges recovered nearly 380,000 gallons of oil and transported 180 cubic yards of contaminated solids.

It is common to begin to structure the elicitation problem by decomposing both the variables of interest and the questions to be considered by the elicitation.

Some sample questions for our example include:

- What do we mean by oil?
- What is a spill?
- How many ways can oil be spilled?
- What quantities of oil are involved in the different spill scenarios?
- Where does the spill occur?

These may seem to be trivial questions, but it is important to know if oil includes crude winter oil, crude summer oil, diesel, bunker fuel, condensate, gasoline, and so on. Is a spill an unintentional release or any kind of release? Everyone needs to understand the different ways oil can be spilled that they are to be concerned with, e.g., sea disaster for a ship, accident on a single vessel (fire, sinking risk), error entering or exiting harbor, weather conditions, damage to engines, human error, platform accident, lightering, groundings, allision, collision, and the like. It would be important to know the quantities of the different forms of oil that can come into play with different spill scenarios. Will the experts consider spills on land, near the coast, involving the estuary, offshore and how far offshore, and/or in international waters? It is in these matters that the domain experts who are not on the actual panel are most valuable.

Chapter 10 - Training the Experts

10.0 Training the Experts

Many to most experts on your panel will have never participated in an expert elicitation before. They will need to be trained. The best training sessions will have at least three parts. First, experts will be trained in the use of probability and probability distributions. Second, they should be introduced to the most common judgment heuristics and biases people rely on to estimate subjective values as well as ways to overcome them. These heuristics are introduced later in this module. Third, experts should be provided the opportunity to practice elicitations with true answers unlikely to be known by the experts. This may or may not include a calibration exercise to help the experts gage whether they tend to be over or under confident. Once the experts have been trained, the expert elicitation preparation process is complete, and the elicitation begins.

Explore: Expert Elicitation Calibration Exercise

Download the spreadsheet below to complete two exercises on expert elicitation calibration - the first sheet looks at binary calibration; the second sheet addresses quantitative calibration.

In the Binary Calibration exercise, read the questions in column B and enter T (for true) or F (for false) in column C. Estimate how confident you are that your answer is correct, between 50% and 100% and enter that in column D. Scroll over to column E to see how you did.

In the Quantitative Calibration exercise, read each question in column B and estimate a number range that includes the correct answer. Enter your minimum and maximum values in columns H and I. If you are very sure of an answer, enter a narrow range (10 to 15 for example). If you are completely uncertain then enter a very wide range (1 to 1000 for instance). Scroll down to row 97 to see your results.

Calibration Exercise

Chapter 11 - Types of Elicitations

11.0 Types of Elicitations

Here we introduce elicitation, the second step in the process, presented in Figure 1 of Chapter 1. USACE experts address uncertainty in a wide range of ways. These include informal and formal elicitations. Informal elicitations are very common within the work of the USACE as you saw in the earlier video on the Tenkiller project. These include:

- Self-assessments where the analyst decides how to quantify more routine uncertain values like those encountered in cost estimates
- Brainstorming
- Causal elicitation without structured efforts to control biases
- Discussion among peers and colleagues[7]

Figure 6. Members of the High-level Experts and Leaders Panel on Water and Disasters (HLEP), include Lt. Gen. Thomas Bostick, USACE Commanding General, came together in April 2015 to collaborate and learn from the experiences of others.

Formal elicitations, the focus of this training, are relatively rare and are generally reserved for the most critical uncertain variables in high visibility, controversial, or critically important analyses. Uncertainty comes in many forms, and expert elicitation can be used to reduce or characterize any of those forms of uncertainty.

A good expert elicitation does not arrive at a consensus value point estimate for any quantity. It is more likely to develop a distribution that describes our uncertainty about the quantity. Then, when it is necessary to develop a single quantity, that value (e.g., mean, median, 95th percentile) can be chosen, with informed consent, from the distribution and used accordingly, presumably with at least some sensitivity analysis.

There are times when we are more interested in the range of potential values or outcomes rather than in any one particular value. In these instances, we could elicit the expert's probability distribution. Examples of values for which a cumulative distribution function (CDF) might be sought include:

- CDF for gallons of oil in a spill at a particular harbor
- CDF for sea level change at a specific location
- CDF for mean cargo tonnage increase attributable to the Northern Sea Route at a specific harbor
- CDF for the useful life in months of an electric barrier for aquatic nuisance species
- CDF for dollar damages from detonation of a dirty nuclear device in New York Harbor

Past events or near-term future events can often be validated, but assessments of occurrences in the future cannot be validated. In the next section, we will develop the CDF for our example, the size of an oil spill.

Qualitative Expert Elicitation

We may ask a panel of experts to qualitatively characterize the key uncertainties in our decision problems or to develop scenarios; narrative responses to questions like the following can help describe the range of possibilities.

- How will climate change affect the agriculture and population patterns of the Skagit Valley in Washington?
- How will the Northern Sea Route affect the quality of life among indigenous coastal populations of Alaska?
- How might normalization of trade with Cuba affect ports in South Florida?
- What will be the long-term effects of the innovative financing of pilot projects included in the Water Resources Reform and Development Act of 2014 on the USACE project authorization and appropriation process (see http://www.usace.army.mil/Missions/CivilWorks/ProjectPlanning/LegislativeLinks/wrrda2014.aspx)?

Quantitative Expert Elicitation

We may be very interested in a specific value of a quantity, variable, or in the value of a specific parameter. Example questions for this type of information include:

- How many feet will mean sea level rise or fall in Skagit Bay by 2075?
- How many barrels of recoverable oil are located within the Alaska National Wildlife Refuge?
- What will be the maximum draft of an ocean going vessel in 50 years?
- What will be the maximum hourly number of containers that can be loaded or off loaded from a container vessel in 2050?

Probability Expert Elicitation

A special subcategory of values is of great interest in many USACE problems. This is the probability of an event, especially the probability of failure. Eliciting these kinds of values requires experts to have had special training. Example questions for this type of information include:

- What is the probability that one or more tainter gates in the Northwestern Division will fail to operate as designed in the next calendar year?
- What is the probability that any given towboat will encounter a stall at the Maxwell Locks and Dam?
- What is the probability that an innovative new technology will be successful in preventing the spread of a specific aquatic nuisance species?
- What is the probability that this rubble mound jetty will “fail” sometime within the next 5 years?

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[7] EPA. 1997.

Chapter 12 - Eliciting Uncertain Quantities

12.0 Eliciting Uncertain Quantities

The most commonly elicited kinds of uncertain quantities are variables and probabilities. It bears repeating that a good expert elicitation never produces a deterministic estimate of an uncertain quantity. It may, at times, however, be called upon to describe a qualitative variable or to characterize the uncertainty about an unknown constant or parameter. Often, expert elicitation will be used to specify a probability distribution to characterize the uncertainty about a variable. This latter case is the most sophisticated approach and the focus of this discussion. There are three ways to ask experts to specify a probability distribution. They could:

1. Specify the cumulative distribution function (CDF)
2. Specify the probability density function (PDF)
3. Choose a standard distribution and specify its parameter values

The most common way, and the one described here, is to specify the CDF. There are two basic ways to do this. In the "fixed interval approach," the elicitor chooses a value for the variable of interest (**x** value) and requests the expert's corresponding probability that this value will be exceeded or fallen below (**p** value). In the "variable interval approach," the elicitor chooses a **p** value and requests the expert's corresponding **x** value.

Explore: Oil Spill Example

The example provides an example of the variable interval approach, where the elicitor chooses a **p** value and requests the expert's corresponding **x** value.

Example: Oil Spill

In this example we look at an expert elicitation example. It is helpful to see an example to frame the discussion that follows in this course. Imagine a local port authority in partnership with the U.S. Army Corps of Engineers is considering expanding its oil handling capacity in a harbor. The project delivery team is considering changes to the depth and width of existing navigation channels that would support the expanded oil handling capacity. One of the potential risks of greatest concern is the effect of an oil spill on the environment. An initial consideration of this risk has identified the size of the oil spill as a significant uncertainty and the uncertain quantity to be characterized by an expert elicitation.

For simplicity, assume you are interested in the total cost of cleaning up an oil spill. To keep the example from getting bogged down in confusing realistic details that would only distract us let's assume the total costs of cleaning up one gallon of spilled oil is $250/gallon. What you need to know is the expected value of an oil spill clean-up.

Let's look at the model. It is trivially simple. Total cleanup cost is the decision variable and model output, shown in red. Inputs, in blue, include the cleanup cost per gallon and the number of gallons spilled. Total cleanup cost is the product of the two inputs.

The obvious problem is that the new channel and port activities do not yet exist so there is no way for you to know with certainty what the spill size will be if a spill occurs. It is also impossible to acquire real data in advance of the harbor improvements. You have a data gap in your decision problem that can be filled by expert opinion and we'll use a simple expert elicitation to extract the knowledge our expert has.

Imagine a suitable panel has been convened and the problem has been structured carefully. This structuring would consider questions like these as well as the available data on open water oil spills such as that shown here. Let's keep this example as free of complications as we can for now and let the elicitor begin the process. We begin by asking the expert to consider all the relevant factors we have researched, discussed and clarified when preparing for the elicitation. Let us begin with the absolute minimum size of an oil spill that you can imagine in the new harbor. Knowing the amount of fuel being processed our expert says 1 gallon is the minimum size oil spill that could occur in the new harbor. Our expert supports this choice with several vivid examples.

Next, we ask for the absolute maximum size oil spill. Our expert describes a sequence of events that could lead to a catastrophic spill of 4 million gallons.

Now we know a spill will be between 1 gallon and 4 million gallons. So we now ask him to choose a spill size between these two bounds such that half of the spills will be larger and half will be smaller than that number. Our expert says that half of all spills will be less than 750 gallons and half will be more. He describes situations producing many small spills as evidence. That is the median value. It defines a bottom half and a top half so now we will seek values that will divide those two halves in half. The expert offers 500 gallons as the mid-point for the smallest spills and 1.5 million gallons as the mid-point for the largest spills. In effect, he expects spills of 500 gallons or less 25% and 25% of the time he expects spills to exceed 1.5 million gallons.

Notice we have generated a set of **X**-**P** pairs, spill sizes are the **x**'s and their corresponding cumulative probabilities are the **P**'s. This is enough to generate a cumulative distribution. Using the @RISK software from Palisade Corporation we can look at the cumulative distribution function you just generated. The CDF is an example of a common output of an expert elicitation.

When we insert the distribution into our model and multiply it by $250 we can now simulate the total clean-up cost for an oil spill.

Notice the average cost is about $220 million and there is about a 50% chance a spill will cost $1 million or more. In this example an expert elicitation was the only way to obtain data to complete the calculation you needed to estimate the cost of cleaning up an oil spill.

Now that you have an idea what the result of an expert elicitation looks like and how it could be used in an analysis, let's go back to the course and begin to fill in some important details.

Now that you have seen a variable interval example, let's consider how a fixed interval estimate of the oil spill size would differ. When the range of a variable, **x**, is known, it may be easiest to choose a value of **x** and then ask for the corresponding cumulative probability. Consider these examples for a continuous oil spill size variable with a bounded range from 1 to 4,000,000 gallons like the video example.

- What is your probability that an oil spill is less than or equal to 200 gallons?
- What is your probability that an oil spill is less than or equal to 1,000 gallons?
- What is your probability that an oil spill is less than or equal to 100,000 gallons?
- What is your probability that an oil spill is less than or equal to 1,000,000 gallons?
- What is your probability that an oil spill is less than or equal to 3,000,000 gallons?

If the variable does not have defined bounds, then it will be necessary to ask the expert for their minimum and maximum values. Strategically, questions are usually asked about the extreme values first in order to minimize overconfidence. This question would be some form of "What is the highest (lowest) value that you can imagine?" Followed by, "How could this occur?" Once the expert gives their estimate, the facilitator will often probe the thoughtfulness behind the extremes. Once the bounds are established, the remainder of the questions are like those above.

EXPLORE: ELICITING A PROBABILITY

Let's look at an elicitation interview for an example of how to develop bounds for an uncertain variable.

Example: Elicitation Interview

Elicitor: What is the maximum number of marine casualties that can occur in the new channel in a year?

Expert: 35.

Elicitor: How would that happen?

Expert: The new channel is wider and safer, a lot of the accidents that occur now are because the channel is too narrow at some critical points. If you widen the channel you could cut the accident rate by virtually half.

Elicitor: Imagine that you left the area for ten years or so and did not keep up with navigation while you were away. Suppose when you returned you learned there had been a maximum of 45 accidents in the new channel. Can you provide an explanation for how this might have happened?

Expert: Sure. Maybe the wider channel provides a false sense of safety and pilots let down their guard a little, or maybe the mix of traffic could have changed. Most likely a storm or other event that changes the bottom conditions would cause such a jump.

Elicitor: Given your explanation of how the maximum casualty rate could exceed 35 would you like to modify your answer?

Expert: Yes, I think the maximum is closer to 45, maybe 50.

Let's have a quick look at another approach:

EXAMPLE: ELICITATION INTERVIEW USING ACERA'S FOUR QUESTION SEQUENCE

What would explain 50 marine casualties in a year?

ACERA's Four Question Sequence[8]

1. Realistically, what do you think the lowest value is?
2. Realistically, what do you think the highest value is?
3. Realistically, what is your best estimate?
4. How confident are you that your interval from lowest to highest will capture the true value? Please enter a value between 50 and 100%

Let us summarize the fixed interval approach. The approach is simple; the facilitator chooses a relevant x value on the horizontal axis, and the expert provides the corresponding probabilities on the y-axis (**p**(**x**)). From these x-**p**(**x**) pairs, a CDF like the stylized one below can be developed.

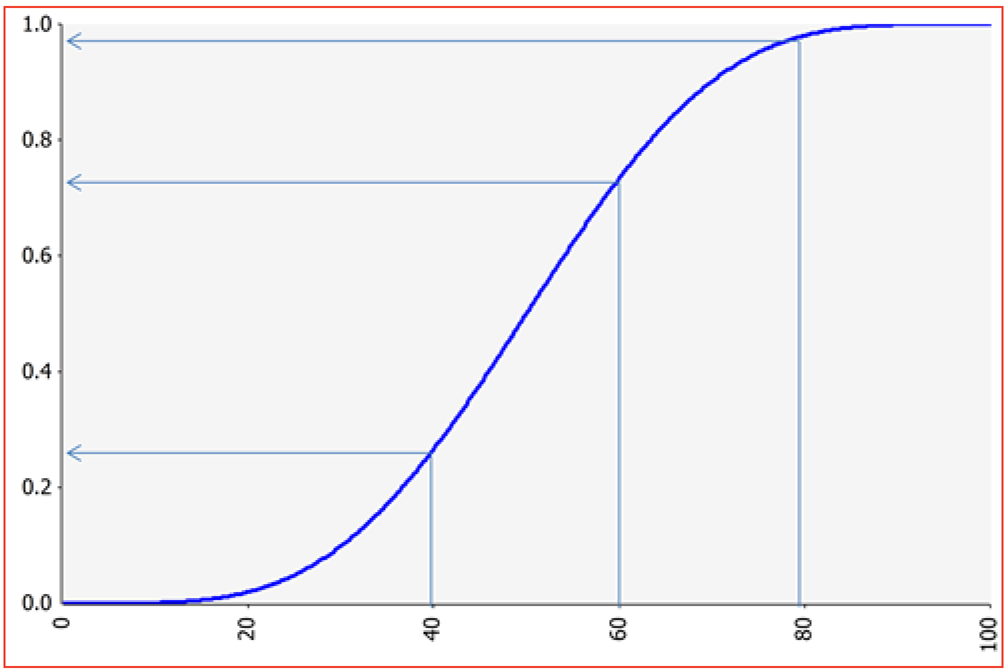

Figure 4. Cumulative distribution function (CDF) for a fixed interval approach.

Alternatively, in the "variable interval approach," of the oil spill example video, the facilitator begins with a cumulative probability value (y-axis) and seeks the **x**-value corresponding to it. The questions often differ in form from what you saw in the video. Here are some alternative forms.

- Suggest an oil spill size such that you are 90% sure an actual oil spill will be less than your estimate.

- Suggest two oil spill sizes such that you are 90% sure an actual oil spill will lie in the interval between them.

The variable interval approach of the video is generically illustrated in the stylized figure below. In this approach, the facilitator chooses probability values from the y-axis, and the expert provides the corresponding x-values on the x-axis. The resulting x-**p**(**x**) pairs can generate the same CDF.

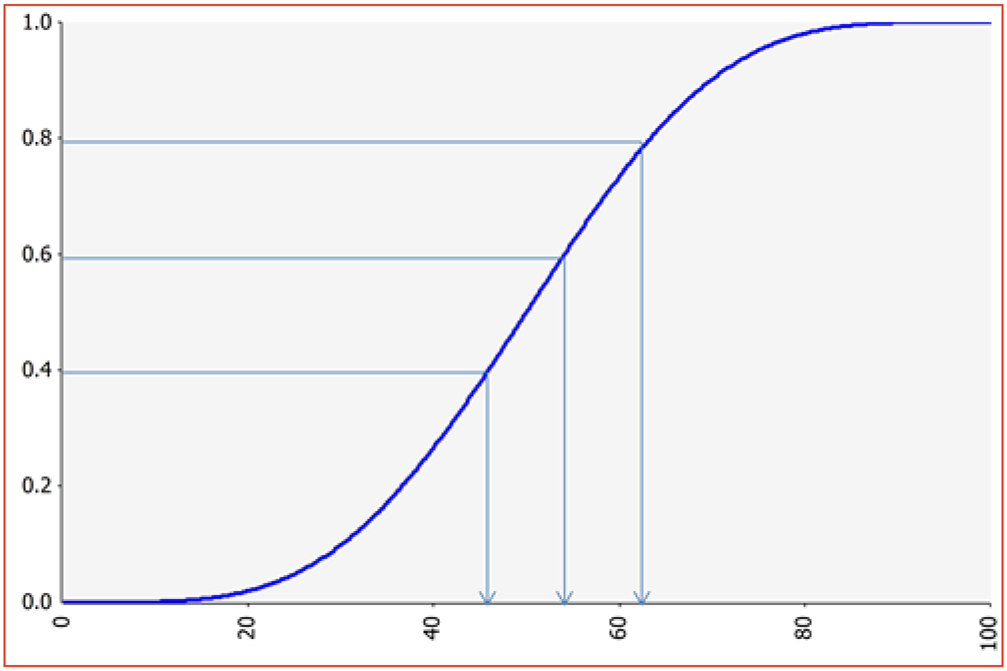

Figure 5. Cumulative distribution function (CDF) for a variable interval approach.

Ideally, the facilitator will present both elicitation methods during training to see which method the expert prefers. When the expert has no preference, the facilitator should choose the method. No matter which elicitation method is used, a minimum of three values should be elicited. The goal is to have the expert identify a most likely value, i.e., the median in the video, then have them identify the magnitude of the uncertainty with bounding values, the minimum and maximum in the video. Ideally, you would then elicit the shape of the expert's distribution with additional values if possible; these were the first and third quartile values in the video.

There is no way to generalize the values to use in a fixed interval method because of the infinite variety of intervals possible. However, some common elicitation value choices for the variable interval method are shown below:

- Elicit the quartiles-the median (0.5), lower quartile (0.25), and upper quartile (0.75).
- Elicit the tertiles (0.33 and 0.66 quantiles).
- Elicit the median, the 0.05 quantile, and the 0.95 quantile.
- Elicit the median, the 0.17 quantile, and the 0.83 quantile.

These values may or may not be elicited along with the minimum and maximum values. This expert elicitation task is concluded once the expert's values have been obtained.

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[8] Australian Centre for Excellence for Risk Analysis (ACERA). 2010.

Chapter 13 - Combining Estimates

13.0 Combining Estimates

Synthesis is the third and final general task in the elicitation process. It begins once all experts have offered their opinions. A good expert elicitation uses multiple experts. Multiple experts will likely produce multiple and diverse estimates. After the results of an expert elicitation are obtained, they may be described by any one of the following scenarios:

1. Individual elicitations that are not combined
2. Individual elicitations that are combined by the expert panel itself
3. Individual elicitations that are combined by the sponsors of the elicitation
4. Expert panel produces a single group elicitation

Sometimes the range of estimates is the desired output of the expert elicitation. Each expert's opinion can then be separately used to describe an uncertain situation, run a model, or complete an analysis in a rigorous sensitivity analysis. This is the case in Scenario 1; estimates do not have to be combined. Remembering that consensus is not certainty, there may be instances where the expert panel may be asked to produce a single estimate for each uncertain quantity as is provided in Scenario 4. Alternatively, the individual expert's elicitations may be combined either by the experts themselves or by the sponsors of the expert elicitation. These situations are described in Scenarios 2 and 3. Scenarios 1 and 3 may be the most common responses to disparate opinions.

The most common means of combining estimates is likely to be simple equal weight averaging. Other techniques require the generation of different weights for different experts. The goal is to give greater weight to the more accurate and informative expert's estimates. Cooke's Classical Method is considered the gold standard for combining expert opinions. The method is based on posing experts a number of "seed" questions from the relevant domain for which the answers are known. Their responses are then assessed to obtain calibration and "informativeness" scores, which are used to develop weights for the responses of each expert. The opinions of the better calibrated and more informative experts receive greater weights when combining the elicitations to develop a single curve that represents the opinion of a "synthetic decision maker[9]." Full mathematical details can be found in Cooke.[10]

EXPLORE: COMBINING OIL

The following example provides a simple overview of how multiple estimates can be handled.

Combining Oil

In this example we will consider the question of whether or not to combine expert elicitations. There is an extensive literature on the pros and cons of combining the judgments of experts into a single summary or consensus distribution that is sometimes called a “synthetic decision maker.” One option is do not combine them. Instead, use the individual results to display the range of expert judgment. If the experts are using very different underlying models of the science, a combined distribution may not adequately represent anyone's judgment. It would be analogous to the proverbial example of a person with one foot on fire and the other frozen in a block of ice who, on average, is comfortable.

Let’s return, briefly, to our earlier example of an oil spill size elicitation. We saw how a single elicitation could produce a cumulative distribution function. A group elicitation or a group of individual elicitations, however, produces several such functions. Once the elicitations are completed you have to decide whether and how the elicitations are to be combined.

Let’s imagine that your expert panel produced four elicited cumulative distribution functions as seen in the table here. Ordinarily you would have more experts on a panel but let us keep the arithmetic of this example simpler with just four functions from four experts. Notice that everyone has offered spill sizes for the same cumulative probability values.

Individual elicitations produce a more diverse spectrum of responses that usually provide the most robust picture of uncertainty but they do not necessarily promote or represent consensus. Here is how your CDF looks. Let’s have a look at that diverse spectrum.

Consider the CDF view of the size of an oil spill. The vertical axis shows the cumulative frequency, you can think of this as the percentile value. Let’s go to .6 or the 60th percentile. The blue curve is expert B and B believes there is 60% chance an oil spill will be 180,000 gallons or less. Expert A in red believes there is a 60% chance the spill will be 600,000 gallons or less, while expert D in purple believes the 60th percentile spill is 1,160,000 gallons or less and expert D in green believes this value is 1,440,000 gallons or less. The average of those values is 840,000 gallons and that is not representative of any expert’s opinion.

Let’s reverse our orientation now and begin with a spill of .5 million gallons. Notice how the cumulative probability or associated percentile values vary from expert to expert. Green considers this 35th percentile value, purple calls it 44th, red is 58th percentile and blue believes that 82 percent of all spills will be half a million gallons or less. Averaging these values would mask this diversity of opinion.

Another option we have is to combine the expert opinions. To do that we need values for common probabilities as we have here--values of probabilities for common **x** values could be used as well. One of the most common methods is to use the average values.

In this second example we use the absolute minimum and maximum and average the other values. How does a composite average value affect the information, does it matter? Let's have a look.

When we add the averaged CDF it appears here in yellow and it is clearly distinctly different from the others. We lose a lot of information about the extent of the uncertainty when we combine all four expert curves into a single curve. But we also take all the judgments into account, giving them equal weights.

How can you handle this wide range of views in your analysis.

Averaging is commonly used because it is simple. Some results in the literature suggest this method is as good as any, when your experts are all equally credible and qualified. Other and perhaps more results suggest that your experts are rarely equally credible and when that is so better methods can be found. One of these methods is to give greater weight to the experts that provide better information.

Perhaps one of the most widely applied weighting methods is Cooke's method described at length in this now out-of-print book. His technique cannot be described simply but we might summarize his approach by saying it begins with a series of seed questions relevant to the values being elicited. Answer to these seed questions enable facilitators to develop performance weights that can be used to give more weight to the opinions of experts who perform better on the seed questions.

The literature is full of examples of sophisticated adaptations of Cooke's model most of which require expert support to use.

Another option is to use behavioral aggregation approaches. These approaches have the experts interact in a variety of ways to arrive at a single distribution rather than to produce an individual curve for each expert.

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[9] When the probability estimates from two or more experts are combined the resulting distribution is often referred to as a synthetic decision maker when it is used as the characterization of an uncertain quantity.

[10] Cooke. 1991.

Chapter 14 - Use of Results

14.0 Use of Results

The synthesis of the elicitation continues as analysts use the results of the expert elicitation to support decision-making. Chances are an expert elicitation will be conducted to fill one or more data gaps in an analysis that is essential to decision-making. The elicitation provides useful information, but it does not provide answers or decisions. At its best, depending on the type of elicitation, it may provide a consensus view of the uncertainty about a quantity of interest based on the subjective opinions of a panel of experts. Here is what is important—you cannot treat an elicited value, qualitative description, range of values, or distribution of values as "a fact."

Although the elicited value may be the desired output, the results of an expert elicitation often become inputs to some sort of risk-based analysis. Elicited values may be used to define model parameters. Subjective probability distributions may become inputs to probabilistic risk assessments or Monte Carlo simulations. Differing opinions obtained from an elicitation will provide values that can be used in a sensitivity analysis. Qualitative descriptions obtained may be used for plan formulation, risk management or in other decision making activities.

When faced with uncertainty, especially in controversial or emergency situations, there is often an almost overpowering urge for decision-makers to seek agreement or a clear consensus from experts. Consensus is not certainty. Efforts to force experts who disagree to agree or reach consensus may dampen the value of the work of the elicitation. Sponsors of elicitations and decision makers alike must bear in mind the goal of an elicitation is to quantify uncertainty, not to disguise it through forced consensus or averaging.

The CDF for oil spill size in our example could be used to randomly generate a sequence of oil spill sizes. These values could then become inputs to other models such as the transport and fate models seen below, which show the dispersion of oil at different times after a spill. These model results could then be used to estimate environmental impacts.

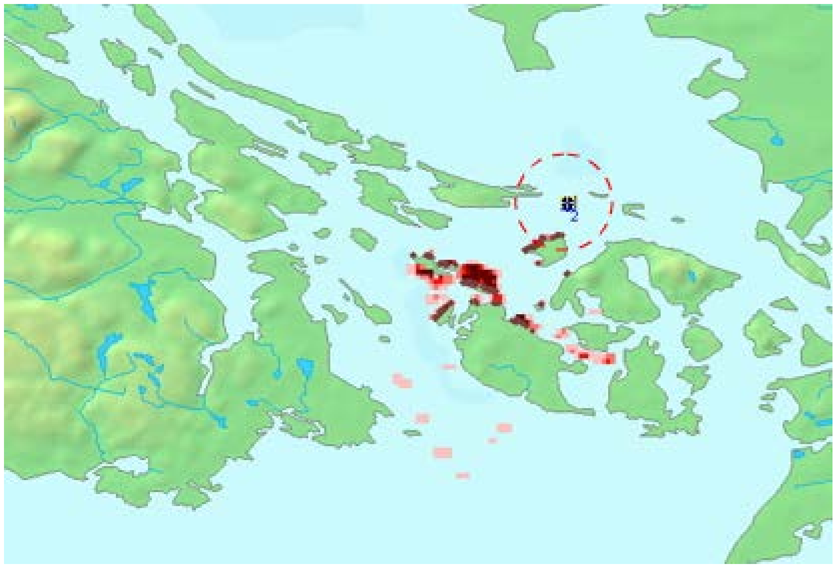


Figure 6. Oil transport on day 1 of spill.

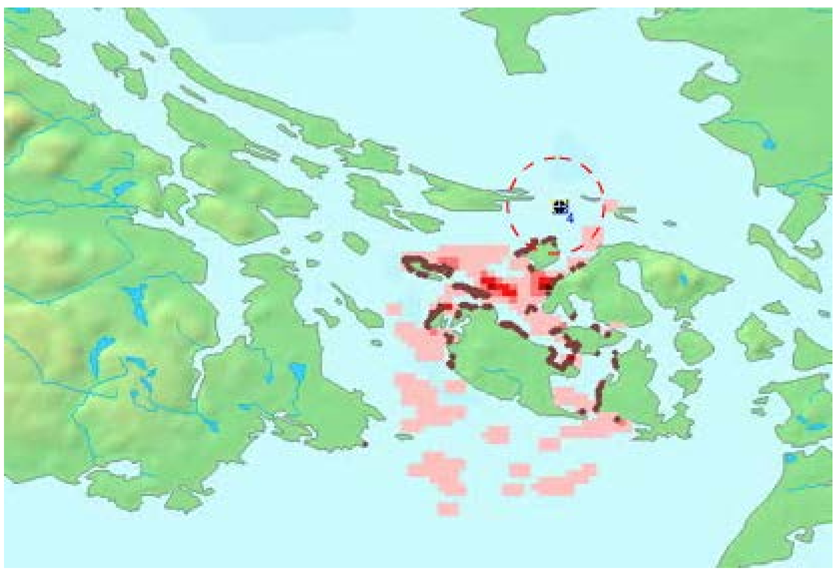


Figure 7. Oil transport on day 3 of spill.

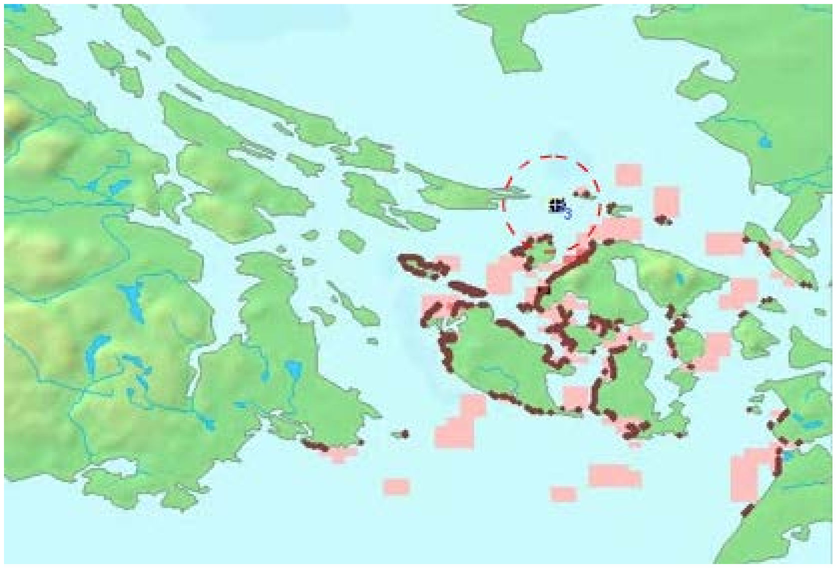


Figure 8. Oil transport on day 7 of spill.

Using the synthesized results or uncertainty characterization from the expert elicitation to support decision-making is the ultimate goal of any good expert elicitation.

Chapter 15 - Protocols

15.0 PROTOCOLS

Now is a good time to formally summarize what we have described. We began our discussion of an elicitation by identifying three elicitation tasks: preparation, elicitation, and synthesis. As you have seen, it is possible, even desirable, to break the process down into more steps. That is what an expert elicitation protocol does. There are many different protocols in use and there is no one right protocol to use. There are many legitimate ways to package the tasks identified in this training module.

The O'Hagan et al.[11] protocol is offered as a good place to start. It is a practical and modern approach that is fully developed in the original source. It comprises the following five steps:

1. Background and preparation – the client (sponsor) identifies variables to be assessed
2. Identify and recruit experts – the choice may be obvious or it may require some effort; six criteria for experts:
    a. Tangible evidence of expertise
    b. Reputation
    c. Availability and willingness to participate
    d. Understanding of the general problem area
    e. Impartiality
    f. Lack of economic or personal stake in the potential findings
3. Motivating and training the experts – assure experts uncertainty is natural; training should have three parts:

    a. Probability and probability distributions
    b. Introduction to most common judgment heuristics and biases as well as ways to overcome them
    c. Practice elicitations with true answers unlikely to be known by the experts
4. Structuring and decomposition – spend time exploring dependencies and functional relationships that meet agreement by experts; precisely define quantities to be elicited
5. The elicitation – an iterative process with three parts:

    a. Elicit specific summaries of expert's distribution
    b. Fit a probability distribution to those summaries
    c. Assess adequacy: if adequate stop, if not, repeat the process with experts making adjustments

Other protocols exist that could be more appropriate to meet your needs. You should feel free to choose a protocol that best meets your needs, but every expert elicitation should follow a protocol. For comparison two other protocols that have been popular in the literature are summarized below.

Stanford/SRI Assessment Protocol

The Stanford/SRI Assessment Protocol described by Morgan and Henrion[12] is one of the earliest and simplest protocols. It consists of five phases:

1. Motivating – establish rapport with experts, explain need and process, explore motivational bias
2. Structuring – develop unambiguous definition of quantity to be assessed in a form meaningful to experts
3. Conditioning – get expert to think fundamentally about their judgments while avoiding cognitive biases
4. Encoding – elicit and encode the expert's probabilistic judgments
5. Verifying – test judgments to see if they reflect experts beliefs

Clemen and Reilly Method

Clemen and Reilly[13] developed an updated protocol that many have found useful. It is a seven-step method:

1. Background – identify variables requiring expert assessment; review scientific literature
2. Identification and recruitment of experts
3. Motivating experts – establish rapport with experts and generate enthusiasm for the process
4. Structuring and decomposition – explore the experts' understanding of causal and statistical relationships among the relevant variables
5. Probability assessment training – explain the principles of the assessment, the biases, and ways to counter them; provide opportunities for experts to practice making probability assessments
6. Probability elicitation and verification – experts make required assessments under the guidance of a facilitator; assessments checked for consistency and coherence
7. Aggregation of experts' probability distributions – if multiple experts were used, it may be necessary to aggregate their assessments

[11] O'Hagan et al. 2006.

[12] Morgan and Henrion. 1990

[13] Clemen and Reilly. 2001.

Chapter 16 - Heuristics

16.0 HEURISTICS

Expert elicitation can be a very effective means of characterizing critical uncertainty in decision problems. However, the results of an expert elicitation can be weakened by the heuristics and biases that humans rely on to think about complex problems. Heuristics are mental shortcuts that allow us to solve problems and make judgments quickly. Without heuristics, we might spend all of our time thinking. All of the heuristics you are going to read about here are useful shorthand ways to make sense of a complex universe. In the right circumstances, they can be trustworthy ways to think about problems. However, our minds resort to these mental shortcuts automatically, and we do not often have control over their appearance and use in decision-making. Worse, they often mislead us or introduce errors to our thinking, as you will learn.

The heuristics of most interest during an expert elicitation include:

- Motivational bias – when the motives of the expert influence her estimates
- Availability heuristic – relies on examples that come immediately to mind
- Representativeness – use of familiar events believed to be comparable, expert assumes the probabilities will be similar
- Anchor and adjust – beginning with a value or anchor and then estimating a minimum and maximum value by subtracting it from and adding it to the anchor
- Framing effect – estimates that depend on whether the outcomes are presented as a loss or as a gain
- Confirmational bias – tendency to selectively search for and consider information that confirms one's beliefs

The literature on heuristics is immense. One of the best introductions to this topic is in the article, "Judgment under Uncertainty: Heuristics and Biases".[14]

Minimizing the effects of potential biases is important. Making expert panel members aware of these heuristics and their biases is an essential part of effective expert elicitation training.

Motivational Bias

Motivational bias occurs when the motives of the expert influence their estimates. This can occur for many reasons. People may want to influence the outcome of an elicitation or the project it supports. There are varieties of motives that can bias an expert.[15] Experts may:

- Want to influence a decision
- Perceive they will be evaluated based on the outcome
- Suppress their uncertainty to appear more knowledgeable

- Desire to work for one of the parties involved in the decision problem
- Have a strong position on a question
- Be cock-eyed optimists or perpetual pessimists.

Any of these outlooks can bias an estimate. People who favor the harbor improvements in our example might construct responses to make risk of oil spills look smaller than it might in fact be.

Availability Heuristic

The availability heuristic relies on examples that come immediately to mind. It operates on the notions that we remember the important stuff, or if we can remember something, it must be important. The truth, however, is the availability of an idea is heavily weighted by the recentness of the information and the magnitude of the consequences. The ease with which an idea comes to mind tends to increase our assessment of its probability of occurrence. The probability of a given flood is routinely overestimated when that flood has occurred recently. Likewise, the probability of a flood in areas that have been flood free for some time tends to be underestimated. If a large oil spill, like the Deepwater Horizon, has been in the news recently, some experts may overestimate the probability of an oil spill in our example.

See an example of an availability bias below.

Availability Heuristic Example

Inverviewee: "I'm telling you smoking does not cause cancer. My grandfather smoked three packs of cigarettes a day and he lived to be 100."

Analysis: The interviewee is using an anecdote to support his bias as if it proves his proposition. We don't actually have enough information to support the proposition. This is a classic example of availability bias.

Representativeness

To judge the probability of an event, many people find a familiar event they believe to be comparable and assume the probabilities will be similar. One might estimate the probability of marine casualties by reasoning they are like driving accidents though not as frequent because there are more cars than ships. They would then estimate the rate of marine casualties by scaling down automobile accident rates. That is not a valid comparison. Most of us expect relationships that hold true in the large to be reflected in the small, which is not always the case. These kinds of tendencies give rise to the representativeness heuristic and its related biases. Using oil spill data from an unrelated site could be a source of representative bias. The quiz below introduces several examples of representativeness bias.

Heuristics: Representativeness

It's time to check you knowledge about Representativeness.

Let's use this short quiz to learn about the representativeness heuristic.

1. Law of Small Numbers

Which ten coin toss result is most likely to occur in one toss of ten coins?

a. The first (top) result
b. The second (bottom) result
c. Neither can occur
d. They are both equally likely

2. Conjunction Fallacy
Linda is 31 years old, single, outspoken, and very bright. She majored in civil engineering. As a student, she was deeply interested in flood problems, dam safety and saving lives. As a student she did an internship with the U.S. Army Corps of Engineers and loved it. She got glowing reviews from USACE. Please check off the most likely alternative:

a. Linda is an engineer
b. Linda is an engineer and a Corps employee

3. Base Rate Neglect
Consider the following supposition:

- US population ~300,000,000
- Terrorists in US ~ 3,000

Imagine a new technology that monitors all communications and within 3 words can detect a terrorist with 99% accuracy

- T+=99%

- F+=1%
- FBI is automatically contacted

When the FBI gets a report from this system, what is the probability it has a real terrorist?

a. 99%
b. 98%
c. 95%
d. 50%
e. 5%
f. 2%
g. 1%
h. 0.1%

4. Confusion of the Inverse
Suppose 90% of all levees that breach have seepage problems. What is the probability a levee with a seepage problem will breach?

a. It is also 90%
b. It is more than 90%
c. It is less than 90%
d. There is not enough information to say.

5. Confounding Variables
Consider the following assessment and decide whether it's true or false. A lock with 10-year old gates malfunctions on 1% of all lockages. An estimate of malfunction frequency is needed for a lock with 20-year old gates and the same lock design. Because the lock is trice as old it is reasonable to estimate the frequency of malfunction as twice as often or 2%.

a. True
b. False

Heuristics: Representativeness - ANSWERS

It's time to check you knowledge about Representativeness.

Let's use this short quiz to learn about the representativeness heuristic.

1. Law of Small Numbers

Which ten coin toss result is most likely to occur in one toss of ten coins?

a. The first (top) result
b. The second (bottom) result
c. Neither can occur
d. They are both equally likely

ANSWER: d. They are both equally likely

Consider a toss of ten coins. Each has a probability of .5 x .5 x .5 x .5 x .5 x .5 x .5 x .5 x .5 x .5 = 0.000977. They are both equally likely. Most people say the bottom is most likely because it looks more random.

2. Conjunction Fallacy
Linda is 31 years old, single, outspoken, and very bright. She majored in civil engineering. As a student, she was deeply interested in flood problems, dam safety and saving lives. As a student she did an internship with the U.S. Army Corps of Engineers and loved it. She got glowing reviews from USACE. Please check off the most likely alternative:

a. Linda is an engineer
b. Linda is an engineer and a Corps employee

ANSWER: a. Linda is an engineer

She sounds so much like a USACE employee that we overestimate the probability of that event by ignoring the much greater probability of the base rate condition.

3. Base Rate Neglect
Consider the following supposition:

- US population ~300,000,000
- Terrorists in US ~ 3,000

Imagine a new technology that monitors all communications and within 3 words can detect a terrorist with 99% accuracy

- T+=99%
- F+=1%
- FBI is automatically contacted

When the FBI gets a report from this system, what is the probability it has a real terrorist?

a. 99%
b. 98%
c. 95%
d. 50%
e. 5%
f. 2%
g. 1%
h. 0.1%

ANSWER: h. 0.1%

Let's reconsider that terrorist…

99% x 3,000 = 2,970 correctly identified terrorists (T+)
1% x 299,997,000 = 2,999,970 incorrectly identified nonterrorists (F+)
2,970/(2,970 + 2,999,970) = 0.1%

The high detection rate of terrorists fools us. If we ignore the base rates we get bad estimates of probabilities.

4. Confusion of the Inverse
Suppose 90% of all levees that breach have seepage problems. What is the probability a levee with a seepage problem will breach?

a. It is also 90%
b. It is more than 90%
c. It is less than 90%
d. There is not enough information to say.

ANSWER: d. There is not enough information to say.

People confuse conditional probabilities with their inverse.

In the table below the probability of seepage given a breach, P (S|B) = 180/200 = 90%. The probability of breach given seepage P(B|S) = 180/540 = 33.3%

Type of Seepage	Breach	No Breach	Total
Seepage	180	360	540
No Seepage	20	40	60
Total	200	400	600

5. Confounding Variables
Consider the following assessment and decide whether it's true or false. A lock with 10-year old gates malfunctions on 1% of all lockages. An estimate of malfunction frequency is needed for a lock with 20-year old gates and the same lock design. Because the lock is trice as old it is reasonable to estimate the frequency of malfunction as twice as often or 2%.

a. True
b. False

ANSWER: b. False

Think of all the things that could be different between the two locks besides the age of the lock gates.

Weather, traffic volumes, accident history, frequency of operation, cause of stalls, and so on are all factors that could affect malfunction rates. There are far more things, i.e., confounding variables, than age to consider when estimating malfunction rates.

Anchor and Adjust

When asked to provide an interval to estimate an uncertain value, one of the most common approaches is to begin with a value or anchor that "magically" appears in our minds and then estimate a minimum and maximum value by subtracting an adjustment from and adding an adjustment to the anchor. The problem with this is that even experts fail to make large enough adjustments due to their unwarranted overconfidence. Thus, the size of an oil spill could be over or underestimated depending on the expert's anchor.

Anchor and Adjust Example

How far is it from Baltimore, Maryland to Little Rock, Arkansas if you are driving? Jot your answer down.

Chances are you are not very confident that you have the exact answer so choose a minimum and a maximum distance such that you are 90% sure the true distance is in your interval. Jot that answer down, too.

Most people estimate an uncertain value by starting with a best estimate (i.e., an anchor) and then they adjust the anchor up and down to get their interval. The problem is they typically do not adjust sufficiently. Kahneman and Tversky call this heuristic anchoring and adjustment. The driving distance from Baltimore to Little Rock is 1,050 miles. If your interval includes that value your estimate is good. If it does not, you are normal!

Framing Effect

People often react differently to a choice, depending on whether the outcomes are presented as a loss or as a gain. Suppose three species and 5,000 habitat units will be lost if you do nothing to reverse the environmental conditions causing the losses. Imagine you can choose between Plan A and Plan B. Plan A saves one species and 2,000 habitat units. Plan B loses two species and 3,000 habitat units. Which plan do you choose?

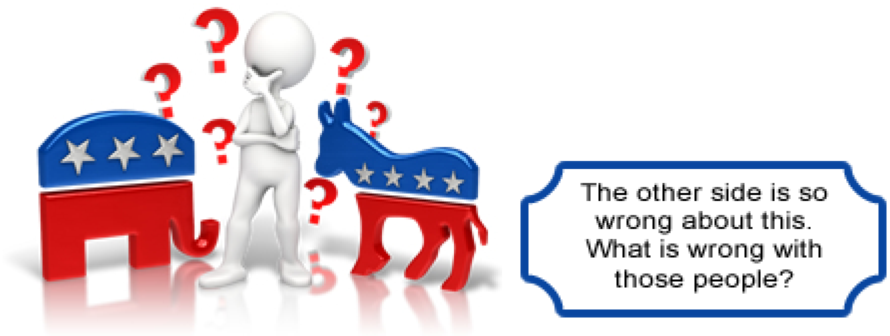
The plans, of course, have identical impacts. The negative frame of Plan B tends to prompt people to avoid the risks of that plan. It is important for the panel to frame a problem in a meaningful way.

Confirmation Bias

Confirmation bias is the tendency to selectively search for and consider information that confirms one's beliefs. In our oil spill example, this could be done by subconsciously paying more attention to data on large spills if one did not realize how many small spills occurred.

Confirmation Bias Example

Take an example from an energetic political general election campaign year. One might think: "The other side is so wrong about this. What is wrong with those people?"



There is often too much information to pay attention to all of it, so we must choose what we read and listen to and we have a strong tendency to select according to what we believe and like to believe. When we attend only to confirming data, we deprive ourselves of the opportunity to have well-reasoned, fair, and accurate beliefs.

Many an expert has been tripped up by an unnoticed confirmation bias.

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[14] Tversky Amos and Kahneman. 1974

[15] Adapted from Morgan and Henrion. 1990

Chapter 17 - Summary

17.0 SUMMARY

Expert elicitation is a valuable technique for filling holes in one's data. It can be used to flesh out uncertain scenarios or to characterize the uncertainty about a quantity. Careful preparation for this formal process is essential to its success, identifying, selecting and training experts for the elicitation process are critical preparation tasks. There are many options for the elicitation itself and these include whether to do individual (and how many) or group elicitations as well as how to pose the elicitation questions. Synthesizing the results by getting them into a form that can be used in the intended analysis is the final step of an expert elicitation. Maintaining and using the multiple individual elicitations is often preferable to consolidating them into a single synthetic decision maker form. There are many well-documented elicitation protocols in the professional literature and one of these formal processes should be adopted when an expert elicitation is warranted.

Chapter 18 - References and Resources

18.0 References and Resources

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Chapter 19 - Self Assessment

19.0 Self Assessment

1. Expert elicitation is a well-recognized method for creating new knowledge to fill gaps in data. T or F

2. The quantities to be elicited during an expert elicitation are to be identified by

    a. the client or sponsor of the elicitation
    b. the members of the expert panel
    c. the elicitation team
    d. subject matter experts

3. Which of the following is not an acceptable category of reasons for conducting an expert elicitation?

    a. Data reasons
    b. Expediency reasons
    c. Credibility reasons
    d. Decision reasons

4. Which of the following is not a good indicator of expertise?

    a. Membership and leadership positions in professional societies
    b. Awards and other indications of peer recognition
    c. References from other experts
    d. Media presence

5. Which of the following role layers in an expert elicitation would be most likely to help frame a decision problem for the expert panel?

    a. Expert panelist
    b. Domain expert
    c. Trainer
    d. Facilitator

6. How many experts are recommended for an expert elicitation panel?

    a. Two or more
    b. Eight
    c. Six to twelve
    d. There is no standard recommendation

7. Which of the following is not one of the three parts of the best elicitation training sessions?

    a. Train experts in the use of probability and probability distributions
    b. Structuring the problem with the aid of domain experts
    c. Introduce them to the most common judgment heuristics and biases people rely
    d. Provide the opportunity to practice elicitations with true answers unknown by the experts.

8. What is your probability that an oil spill is greater than or equal to 1,000 gallons?" is the kind of question that would be asked in what kind of elicitation?

    a. A variable interval estimate
    b. Cooke's classical method
    c. A fixed interval estimate
    d. A probability density function method

9. Linda is 31 years old, single, outspoken, and very bright. She majored in civil engineering. As a student, she was deeply interested in flood problems, dam safety and saving lives. As a student she did an internship with the U.S. Army Corps of Engineers and loved it. She got glowing reviews from USACE." Thinking it is more likely she is an engineer and an employee of the USACE is an example of which heuristic?

    a. Motivational bias
    b. Availability heuristic
    c. Representativeness
    d. Framing effect

10. The recentness of the information and the magnitude of the consequences can trigger which heuristic or bias?

    a. Motivational bias
    b. Availability heuristic
    c. Representativeness
    d. Framing effect

19.0 Self Assessment - ANSWERS

1. Expert elicitation is a well-recognized method for creating new knowledge to fill gaps in data. T or F

   False. **CORRECT**. Expert elicitation does not create new knowledge, it characterizes the extent of the uncertainty around our data gaps.

2. The quantities to be elicited during an expert elicitation are to be identified by
   a. the client or sponsor of the elicitation **CORRECT**. The sponsor is to identify the quantities that must be elicited to complete their analytical work. Although the other choices may help to define the quantities they do not identify them.
   b. the members of the expert panel INCORRECT
   c. the elicitation team INCORRECT
   d. subject matter experts INCORRECT

3. Which of the following is not an acceptable category of reasons for conducting an expert elicitation?

   a. Data reasons INCORRECT
   b. Expediency reasons **CORRECT**. Expert elicitation is never an acceptable alternative to gathering data that are reasonably available. Expert elicitation is not an alternative to doing the work and gathering the data.
   c. Credibility reasons INCORRECT
   d. Decision reasons INCORRECT

4. Which of the following is not a good indicator of expertise?

   a. Membership and leadership positions in professional societies INCORRECT
   b. Awards and other indications of peer recognition INCORRECT
   c. References from other experts INCORRECT
   d. Media presence **CORRECT**. Media presence is often a poor indicator of expertise.

5. Which of the following role layers in an expert elicitation would be most likely to help frame a decision problem for the expert panel?

   a. Expert panelist INCORRECT

b. Domain expert **CORRECT**. The domain expert would serve as a resource person to help the expert panel members properly frame the decision problem.
c. Trainer INCORRECT
d. Facilitator INCORRECT

6. How many experts are recommended for an expert elicitation panel?

    a. Two or more INCORRECT
    b. Eight INCORRECT
    c. Six to twelve **CORRECT**. You need at least six experts to assure the robustness of the results. However, the benefits of additional members diminish rapidly with participation of more than 12 people.
    d. There is no standard recommendation INCORRECT

7. Which of the following is not one of the three parts of the best elicitation training sessions?

    a. Train experts in the use of probability and probability distributions INCORRECT
    b. Structuring the problem with the aid of domain experts **CORRECT**. Structuring the problem with the help of domain experts is a critically important part of the elicitation process but it is not a training activity. It is a separate part of the protocol.
    c. Introduce them to the most common judgment heuristics and biases people rely INCORRECT
    d. Provide the opportunity to practice elicitations with true answers unknown by the experts. INCORRECT

8. What is your probability that an oil spill is greater than or equal to 1,000 gallons?" is the kind of question that would be asked in what kind of elicitation?

    a. A variable interval estimate INCORRECT
    b. Cooke's classical method INCORRECT
    c. A fixed interval estimate **CORRECT**. A fixed interval method identifies a value of the x variable and seeks its corresponding probability of occurrence.
    d. A probability density function method INCORRECT

9. Linda is 31 years old, single, outspoken, and very bright. She majored in civil engineering. As a student, she was deeply interested in flood problems, dam safety and saving lives. As a student she did an internship with the U.S. Army Corps of Engineers and loved it. She got glowing reviews from USACE." Thinking it is more likely she is an engineer and an employee of the USACE is an example of which heuristic?

    a. Motivational bias INCORRECT
    b. Availability heuristic INCORRECT
    c. Representativeness **CORRECT**. This conjunction fallacy is a specific example of representativeness.
    d. Framing effect INCORRECT

10. The recentness of the information and the magnitude of the consequences can trigger which heuristic or bias?

    a. Motivational bias INCORRECT
    b. Availability heuristic **CORRECT**. The availability heuristic relies on examples that come immediately to mind. It is heavily weighted by the recentness of the information and the magnitude of the consequences.
    c. Representativeness INCORRECT
    d. Framing effect INCORRECT