Best Practices in Dam and Levee Safety Risk Analysis

I-6. Subjective Probability and Expert Elicitation

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U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RECLAMATION
Managing Water in the West

US Army Corps of Engineers
BUILDING STRONG®

Concepts of Probability

- Flip a coin. It will come up heads.
- The 1,000th digit right of the decimal point in pi is a 7
- There are more than 10,000 telephones in Addis Ababa, Ethiopia
- The 20th president of the U.S. was a Republican
- The U.S. president elected in 2016 will be a Democrat
- The numbers 55, 58, 62, 53, and 52 were obtained by random sampling from a normal distribution with a mean of 50 and a standard deviation of 2
- A vehicle sent on a round trip to Mars will not bring back a pathogen capable of wiping out the entire human race

Ref: Von Winterfeldt and Edwards

Concepts of Probability

- You have information bearing on all these propositions:
  - A coin is symmetrical
  - There are ten possible digits
  - Ethiopia is a poor, not very highly developed country
  - The 20th president was after the Civil War & Republicans did well then
  - You have some ideas what could happen between now and the next election
  - It doesn't seem likely a random process would select numbers all on one side of the mean, and so far from the mean with such a small standard deviation.

Ref: Von Winterfeldt and Edwards

Concepts of Probability

- On the basis of these and other items, you have opinions about the truth of these propositions
- It is the proposition and not the event about which you have an opinion
- Uncertainty is a property of your knowledge about these events, and not of the events themselves.

Ref: Von Winterfeldt and Edwards

Concepts of Probability

- By calculating APF and Risk as we do, we assert that:
  - All uncertainties are inherently of the same kind (insufficient knowledge)
  - Probabilities are useful numbers with which to measure uncertainties
  - Probabilities are personal degrees of belief about uncertain events

Ref: Von Winterfeldt and Edwards

Concepts of Probability

- Three kinds of observations of the real world are related to the probability numbers we use to represent uncertainty:
  - Relative frequency
  - Logical necessity
  - Personal judgments of likelihoods

Ref: Von Winterfeldt and Edwards

Relative Frequency

- Suppose you must decide whether to undergo surgery and the physician says: "My experience with this operation in the past has been excellent. People almost never die on the table, and recovery usually takes a week. In a month you'll be as good as new."
- How useful would it be to replace the verbal statements of uncertainty with numbers?
- One could count the number of times the operation has been performed and the number of times someone has died to obtain a relative frequency of failure

Relative Frequency

- What about the age and physical condition of the patient, the doctor's experience, the nature of potential complications, presence of pathogens and others stuff?
- The desire to properly condition the counting conflicts with the desire to have a large sample.
- Combinations make it difficult to decide to which counting category a particular case belongs

Relative Frequency

- How many times in a day and times in a year do you drive your car?
- When was the last time you got in an accident?
- How would you calculate the probability of getting in an accident each time you drive your car?
- How about the probability per year of getting in an accident?
- Is there something fundamentally different about considering a break-down instead of an accident?

Relative Frequency

- The way the counting is conditioned, affects how appropriate it is to apply it to estimating an event probability
- Changing conditions with time can affect relative frequency
- It’s not perfect, but it’s the best we can do in some cases.

Ways to Obtain Personal Probabilities

- Asking someone who should know to judge the relevant event probabilities

- Use techniques to obtain a judgment on something that can be used to infer a probability (verbal transformation, betting, probability wheels)

Verbal Descriptor	Defined Convention	Experimental Data Reagan et al, 1989
Virtually Impossible due to known physical conditions or processes that can be described and specified with almost complete confidence	0.01	0.02 (0.0 - 0.05)
Very Unlikely although the possibility cannot be ruled out	0.1	0.10 (0.02 - 0.15)
Equally Likely with no reason to believe that one outcome is more or less likely than the other (when given two outcomes)	0.5	0.50 (0.45 - 0.55)
Very Likely but not completely certain	0.9	0.85 (0.75 - 0.90)
Virtually Certain due to known physical processes and conditions that can be described and specified with almost complete confidence	0.99	0.90 (0.90 - 0.995)

Verbal Transformation (Vick, 2002)

Modified

Descriptor	Associated Probability
Virtually Certain	0.999
Very Likely	0.99
Likely	0.9
Neutral	0.5
Unlikely	0.1
Very Unlikely	0.01
Virtually Impossible	0.001*

*Use sparingly – People are not well calibrated below about 0.01

Next Generation Verbal Mapping Scheme

Descriptor	Associated Probability
DUH!	0.999
Ya Think?!	0.99
Totally, Dude	0.9
Whatever	0.5
Yeah Right	0.1
Like, No Way	0.01
NOT!	0.001

Other Verbal Mapping Schemes

- Other schemes are available that may obtain results inconsistent with those obtained using Reclamation
- e.g. Barneich et al (1996), structural reliability classifications, etc.
- "Pedigree" of any system difficult to verify

Expert Elicitation

- Performed by facilitator
- Qualified team
- Process of eliciting “adverse” and “favorable” factors for event tree nodes generates considerable discussion
- Once discussion ends, group is queried for likelihood estimates, and the rationale or justification for the estimates is captured
- An attempt is made to reach consensus, but if it cannot be attained, diverging views are captured along with the reasons for the differences

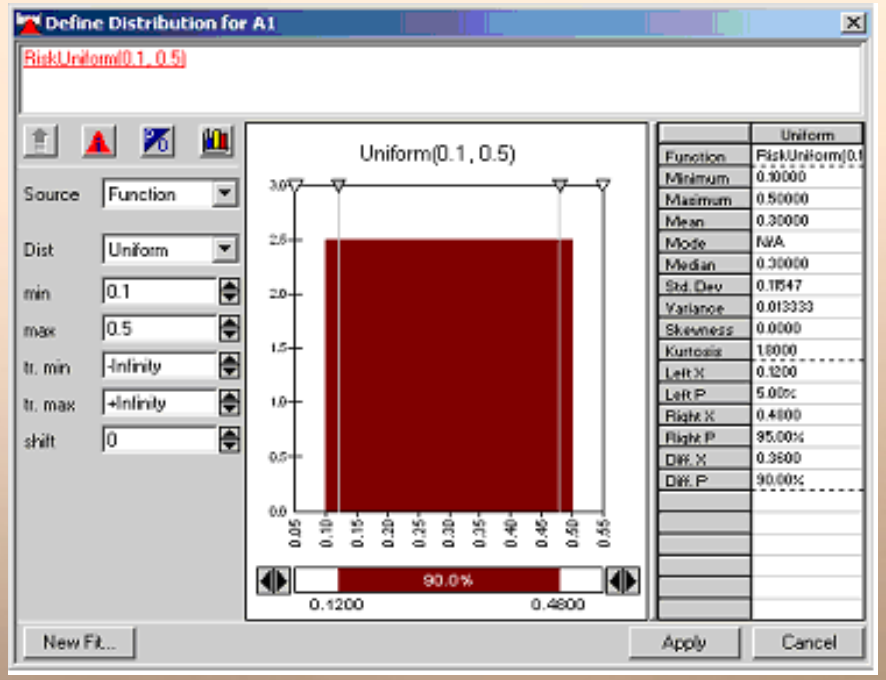
Getting the Elicitation 'Right'

- There are no 'right' answers
- Whose judgment do you want?
- Best if more than 1 expert
- Quantity to be assessed must be clearly defined
- Ask the expert to argue the opposite point
- Any thing that promotes hard thinking and insight helps

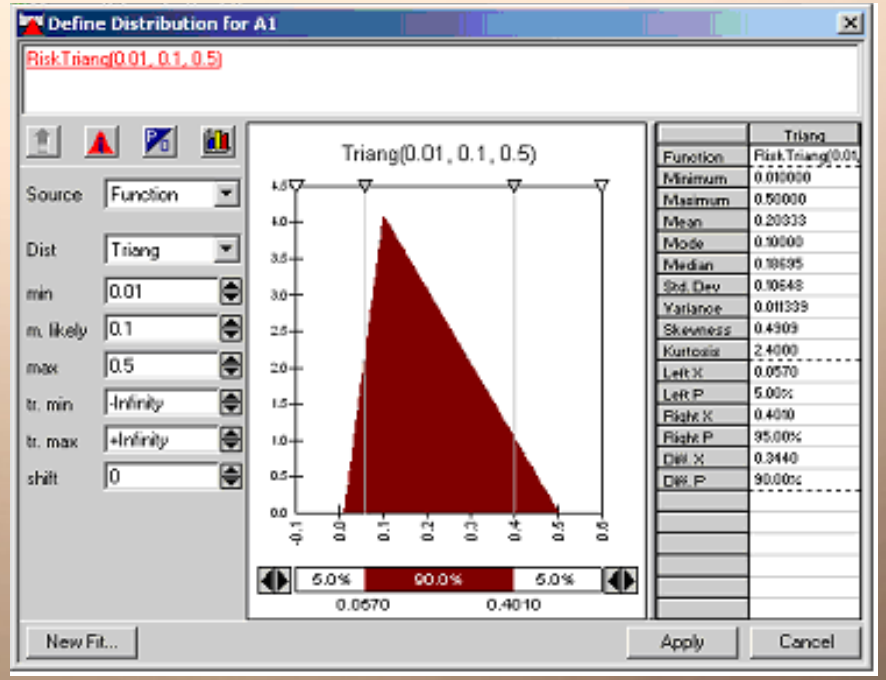
Eliciting Likelihood Distributions

- Possible questions for elicitation
  - What is the lowest you can imagine the likelihood to be?
  - What is the highest you can imagine the likelihood to be?
  - Is it more likely to be somewhere in between these values?

Answers Define Distribution



Uniform Distribution

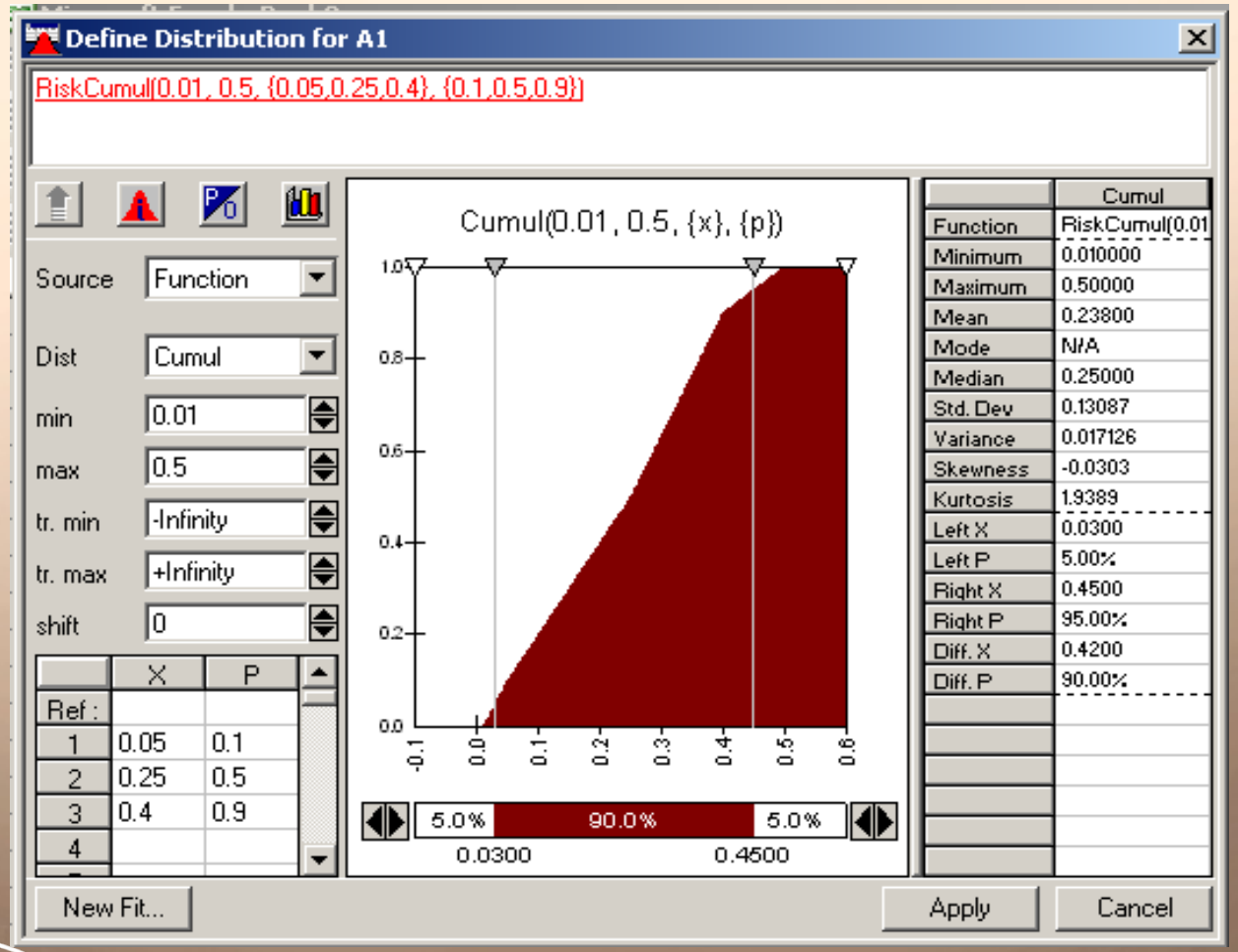


Triangular Distribution

With More Information

- The probability is not likely to be less than _?_ (10th percentile)
- The Probability is not likely to be more than _?_ (90th percentile)
- It cannot be less than _?_ (0 percentile) nor more than _?_ (100th percentile)
- It is equally likely to be more or less than _?_ (50th percentile)

Answers Define Cumulative Distribution



Adjustments to Probability Estimates

- estimates might all clump together about some common number, they might spread over a wide range, clump in two or more groups, or there might be a common group with one or two outliers.
- facilitator should call upon representatives of differing groups to explain why it was they held a particular belief in light of the evidence common to all
- ask if any members of the estimating group might care to change their estimate

Adjustments to Probability Estimates

- Agreement between the estimators might indicate everyone is interpreting the information in the same way.
- Disagreement might indicate that some estimators are mistaken about the importance of particular evidence or that they hold different views in mind about geologic models or design or construction details.
- Disagreement might arise because some estimators may have a difficult time converting degree of belief to a numerical value.

Adjustments to Probability Estimates

- the most important claims and evidence inherent to the controversy can be very helpful when it comes time to develop the dam safety case.
- once again, if consensus cannot be achieved, both estimates are carried forward.
- the opposing viewpoints can often be turned into hypotheses which can be tested by additional investigations.
- to counter the potential for biasing or bullying, facilitators can be provided training to be able to recognize the problems and to be shown techniques to stop them.

Biases

- Overconfidence bias
  - Estimators are more confident than the evidence warrants
  - Range on distributions is too narrow
  - Estimates are closer to 0 or 1 than they should be
  - More expertise can lead to more bias
  - To help avoid, start with an exercise (such as at the end of this section

Biases

- Anchoring Bias
  - Estimates tend not to vary much from those initially presented to a group
  - To help avoid, discuss extreme values before settling on a best estimate
- Availability Bias
  - Estimates influenced by most recent, most easily recalled, or most vivid evidence
  - To help avoid, ensure information that is presented is relevant and counter with opposing view if not

Biases

- **Motivational Bias**
  - Estimators have a vested interest the outcome
  - Designer of dam does not want negative outcome
  - Office needing work wants negative outcome
  - To help avoid, bring out opposing view if opinion appears to be based on motivational bias
- **Representativeness bias**
  - Similarities overemphasized and possible differences neglected
  - To help avoid, ask questions about false positives or false negatives

Group Dynamics

- **Dominant individual**
  - **"Bullies" team into estimating the way they want**
  - **To help avoid, emphasize opposing view and draw others into discussion**
  - **Can also consider instituting "individual estimating" procedures**
  - **(Note: Individual estimating procedures can be instituted in other cases, but when using these procedures, decide how you will select an expected value and distribution)**
- **Quiet individual**
  - **Afraid of appearing unknowledgeable**
  - **To help avoid, draw them out by asking questions specifically of them**

Group Dynamics

- **Burn out**
  - **It's Friday, everyone is tired, and they agree just to get out of there**
  - **Facilitator is likely to feel this way too**
  - **Be alert to this, if it appears to be happening, stop and take a break, then discuss ways to invest proper time in the evaluations**

Exercise

Item	80% Confidence Band	
	Low	High
Abraham Lincoln's age at death		
Length of the Nile River (miles)		
Number of nations in NATO		
Number of studio albums released by the Beatles		
Diameter of the moon (miles)		
Weight of an empty Boeing 747 (pounds)		
Year in which Leonardo da Vinci was born		
Gestation period of an African Elephant (days)		
Air distance from London to Sydney (miles)		
Deepest known point in oceans (feet)		

Answers to Exercise

Item	Answer
Abraham Lincoln's age at death	56
Length of the Nile River (in miles)	4,258
Number of nations in NATO	28
Number of studio albums released by the Beatles	12 or 13
Diameter of the moon (in miles)	2,159
Weight of an empty Boeing 747 (in pounds)	390,000
Year in which Leonardo da Vinci was born	1452
Gestation period of an African Elephant (in days)	660
Air distance from London to Sydney (in miles)	10,562
Deepest known point in oceans (in feet)	36,198