Quantitative Risk Assessment

Risk Analysis training course
NIHE, Hanoi, Vietnam, 4-5 May 2016

Definition

- QRA involves estimating both the **probability** that an unwanted outcome will occur and the **magnitude** of the effect of this occurrence;

- Mathematical modelling process

Steps to model your system

- 7 related steps:
  - **Define the risk to be assessed**
  - Outline the model framework
  - Identify the inputs and acquire the data
  - Adopt an iterative approach to the model
  - Undertake sensitivity testing
  - Ensure clarity by producing a transparent model description
  - Obtain feedback

The RA components in a OIE quantitative framework

- **Release of agent** (from the animal/farm) – EVENTS OUTSIDE END RECEPTOR
  - Starts by using herd and within-herd prevalence data.
  - Looks at pathways in which the infected commodities are not detected under the surveillance system components (sanitary measures; diagnostic tests)

- **Exposure to agent** (exposure of susceptible animal in importing country)
  - Conditional probability
  - The exposure end-point is usually taken as the point of entry into the importing country, not exposure of a susceptible animal – which is harder to estimate.
  - Looks at pathways in which the infected animals (or animal products) are not detected under the sanitary measure (usually diagnostic tests).

- **Establishment, spread and other consequences**
  - Is considerably harder to model
  - Involves dose-response relationship and modelling spread of outbreak, and social, financial and animal welfare costs.

Possible risk management questions

- Annual probability of importing at least one infected animal
- Annual number of infected units imported
- Number of years between entries

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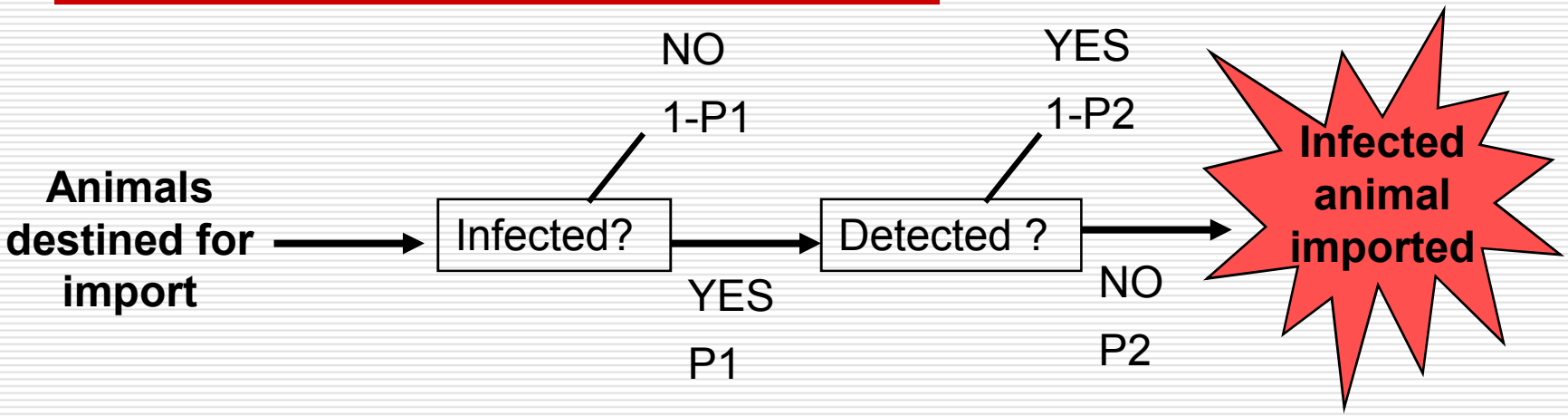
Modelling risk pathways

- **Scenario tree modelling** - graphical method to systematically model the process of disease through a chain of events (i.e. risk events; surveillance system components; release – exposure - consequence)
  - Traces the probabilities that a unit of interest (i.e. animal, herd, flock...) will yield either a positive or a negative outcome
  - Estimate the probability of a given decision
  - Inclusion of factors affecting Pr (infection) and Pr (detection)

Example: simple import RA (1)

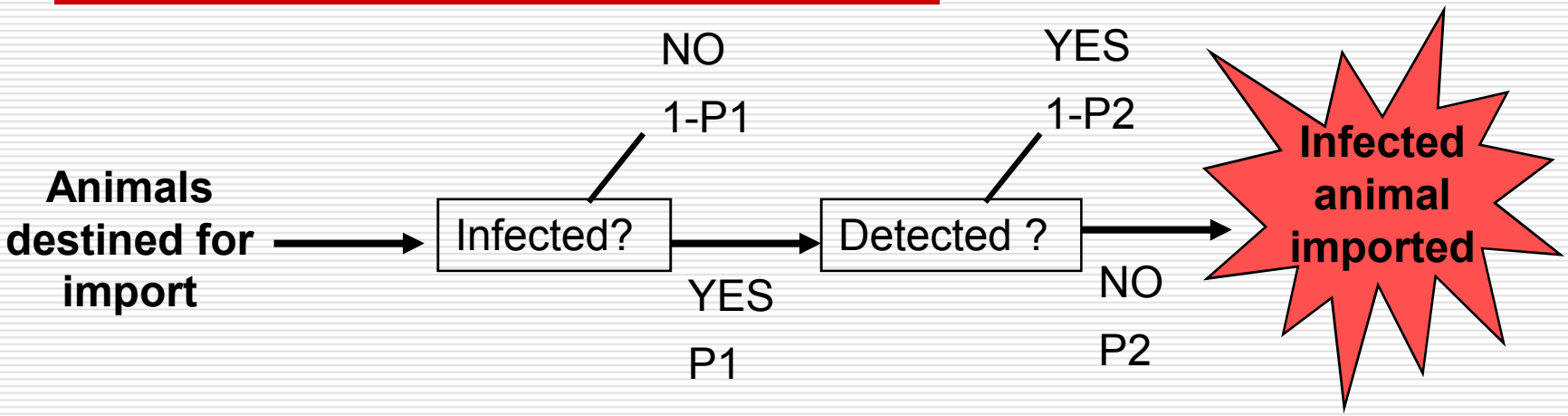


- P1 = probability that animals are infected
- 1-P1 = probability that animals are not infected

Infected animals may or may not be detected by a pre-export test

- P2 = probability that infected animals are not detected
- 1-P2 = probability that infected animals are detected

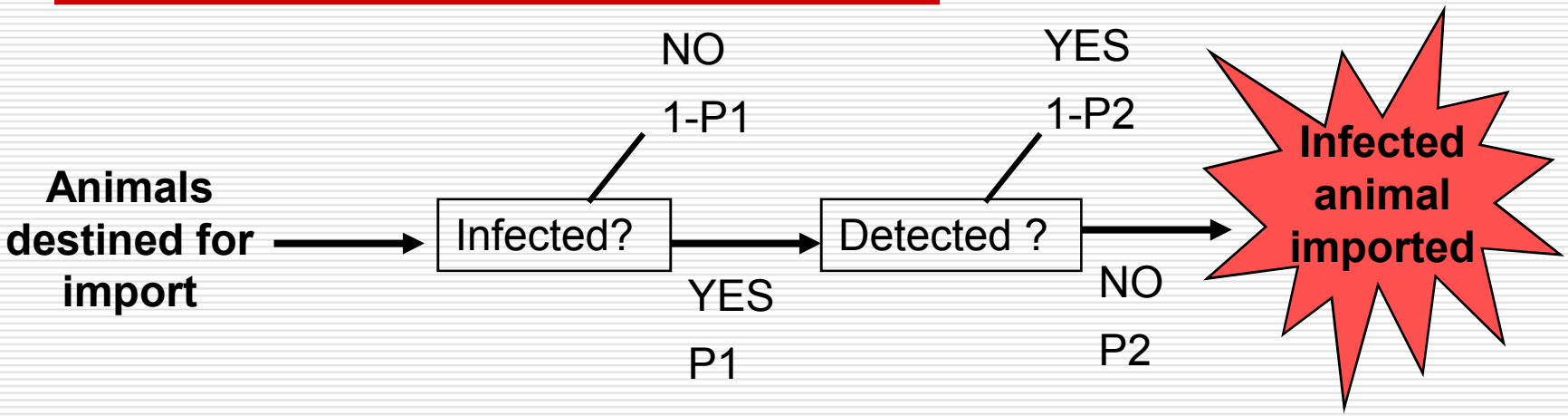
Example: simple import RA (2)



- R = probability that an animal destined for import is infected and gets through testing

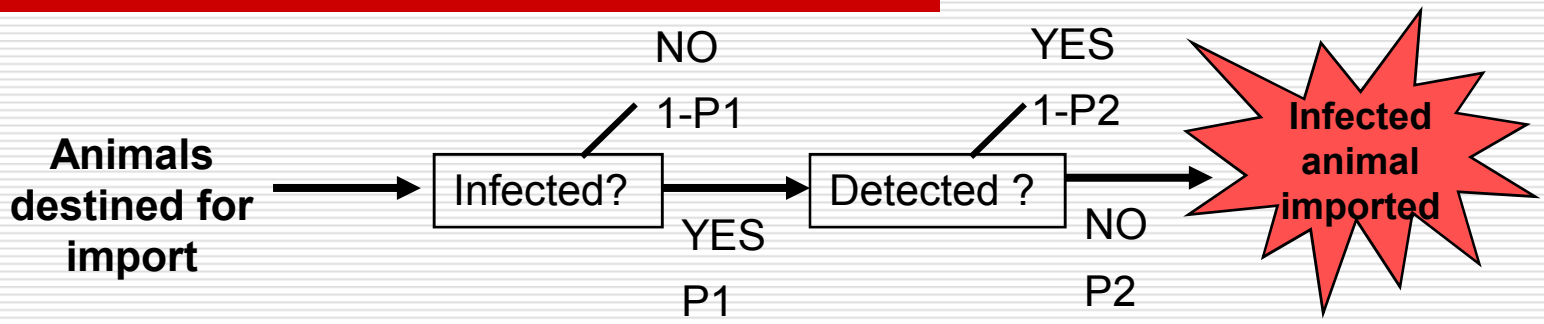
R = P1 X P2

Exercise 1



- An official from the regulatory authorities in the importing country needs to know the probability (R_1) that any animal entering his country is infected. **How to calculate this probability?**

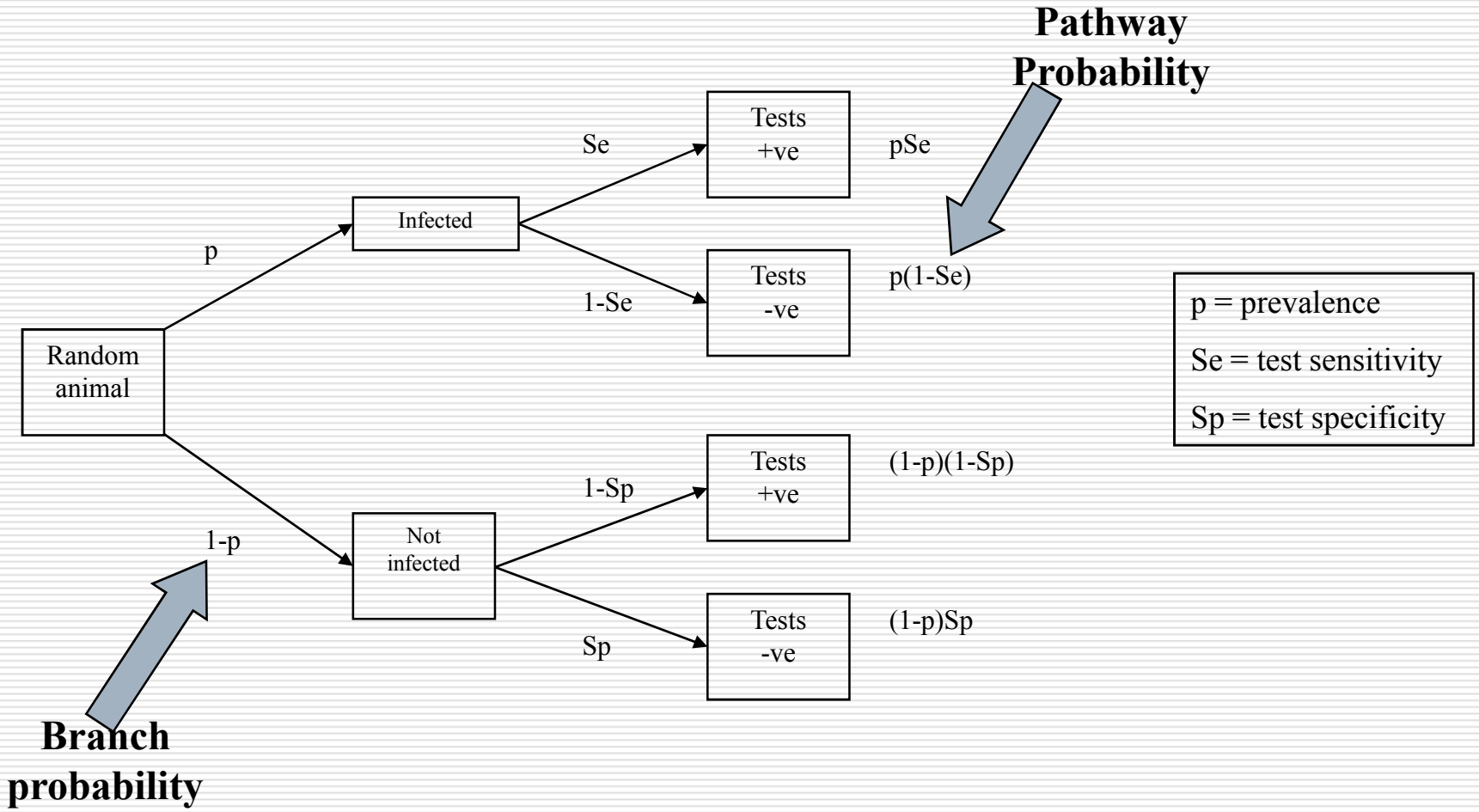
Exercise 1



- R_1 = proportion of animals entering that are infected
  - Proportion of all animals destined for import that eventually enter the country:
    - Infected animals not detected by the test P1P2
    - Animals not infected (1-P1)
    - Animals entering = **P1P2 + (1-P1)**

$$R_1 = \frac{\mathbf{P1P2}}{\mathbf{P1P2 + (1\text{-}P1)}}$$

Estimating "desired" risk



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Identify inputs and acquire data

- For the variables associated with each steps of your pathway you need to associate numbers (from collected data)
- Ex: probability that a random animal is infected with a specific pathogen = prevalence of disease (vary from region, breed, age…)
- You can break down the model pathway into smaller sections to show how inputs and outputs are related to each other

Simulation Inputs

- **Definition:** values from a risky variable which contribute to the models parameters
- Determine type of information – this will determine different approches to develop a distribution based on the source information
  - Source
    - Empirical data
    - Expert opinion
  - Amount
    - Abundant
    - Few
    - Complete absence
  - Representativeness
- Decide if variability from uncertainty must be separated
- Document assumptions

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Iterative approach

- Your model framework will not be complete from the first outline.
- Many cycles of change, followed by discussions, may occur and in this way an iterative modelling approach is adopted

Determinist vs Probabilistic RA

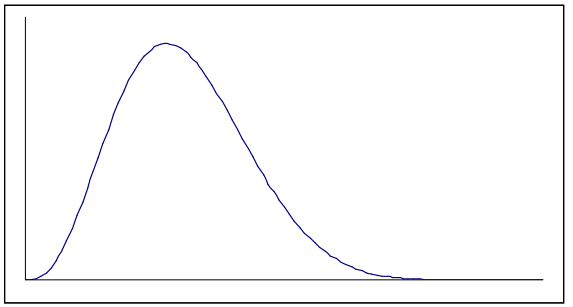
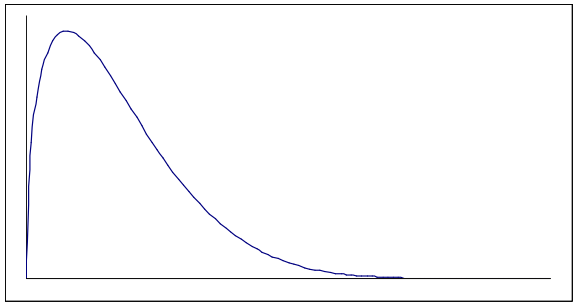
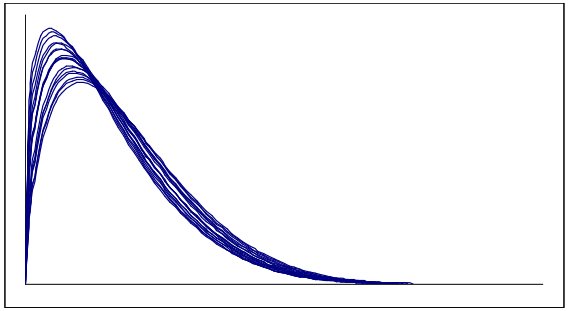
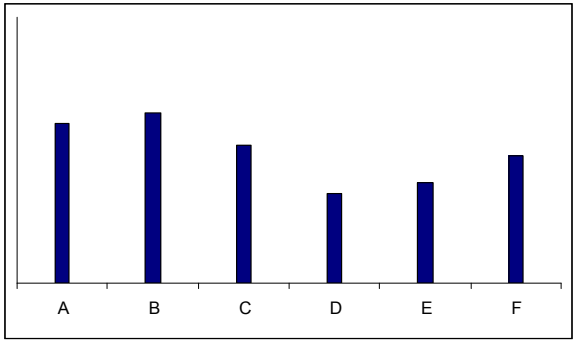
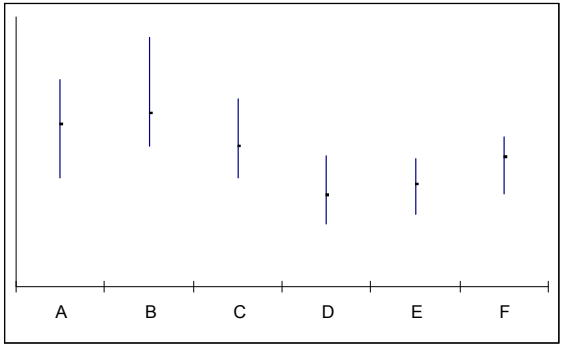
- Deterministic
  - Single (point) values are assigned to each variables
  - Normally a best guess, based on literature or expert opinion.
  - Output is a single value
  - Sensitivity analysis by "what-if" scenario
- Probabilistic
  - Also called stochastic
  - Uses probability distributions to describe variables
  - Range of possible values that a variable can have (e.g. possible weights for cows; prevalence levels within a country)
  - Output is a distribution

Types of data distributions used in risk analysis

- ***Frequency distributions*** describing variability between individual data
- ***Probability distributions*** describing randomness
- ***Uncertainty distributions*** describing assessors uncertainty about some model parameter

  - When we are taking a random sample from a population a frequency distribution is used as a probability distribution

  - When uncertainty about the parameters of the frequency and probability distributions is present we use uncertainty distributions to describe that uncertainty.

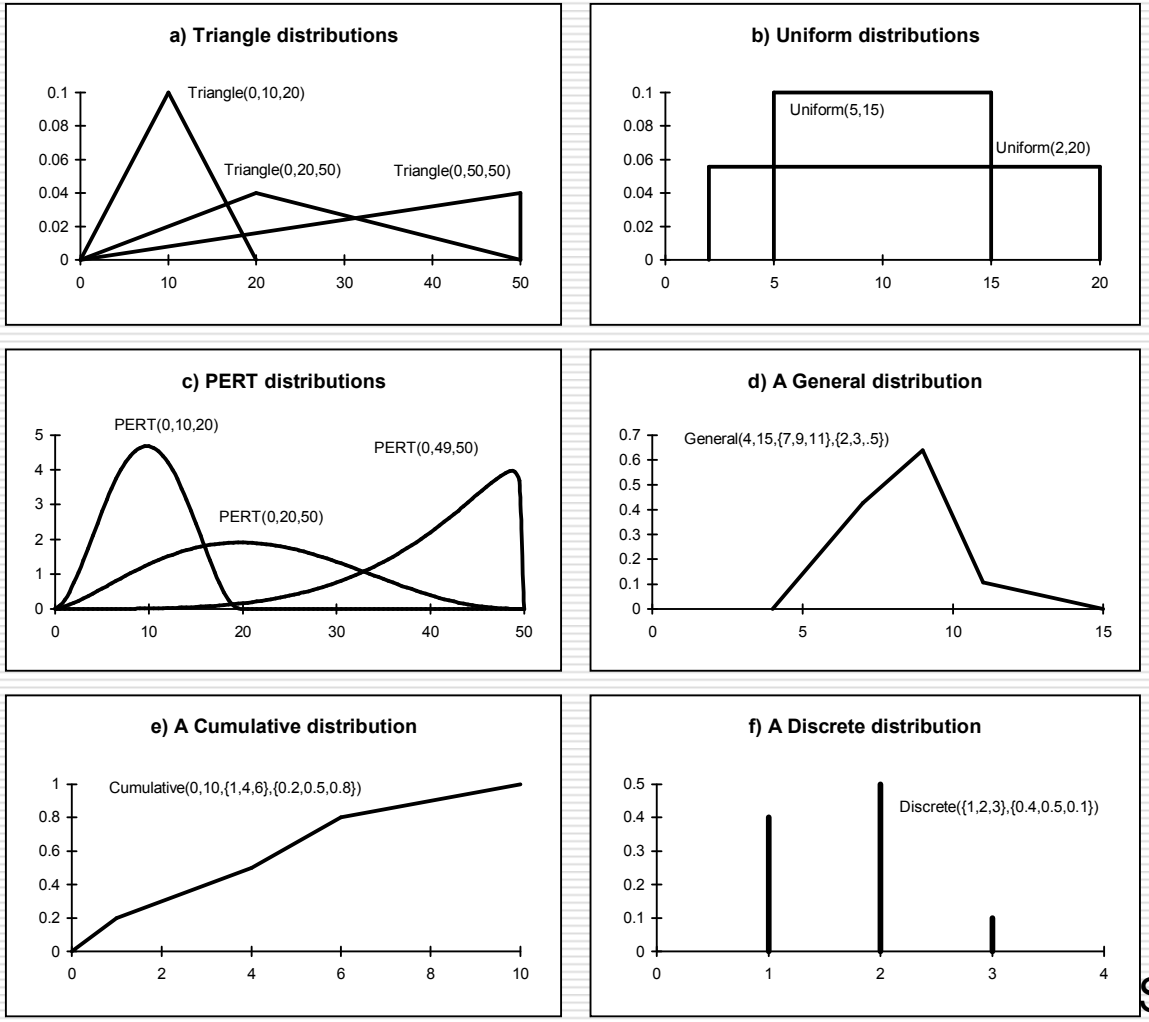
	Randomness only	Uncertainty and randomness
Single-point probability measure	A fixed value	**a)** x = probability measure, y = confidence 
Probability distribution	**b)** x = number ill people (e.g.), y = probability 	**c)** x,y same as b). Multiple lines show uncertainty 
Population variability	**d)** x = sub-group, y = probability measure 	**e)** x, y same as d). Bands show uncertainty 

Source: Vose, 2005

Probability distributions

- Non-parametric distributions useful for empirical data and for modeling expert opinion:
  - Uniform
  - PERT
  - Triangle
  - Cumulative
  - General
  - Discrete
- Parametric distributions also used in literature:
  - Binomial
  - NegBin
  - Beta
  - Poisson
  - Gamma
  - Hypergeometric

Probability distributions



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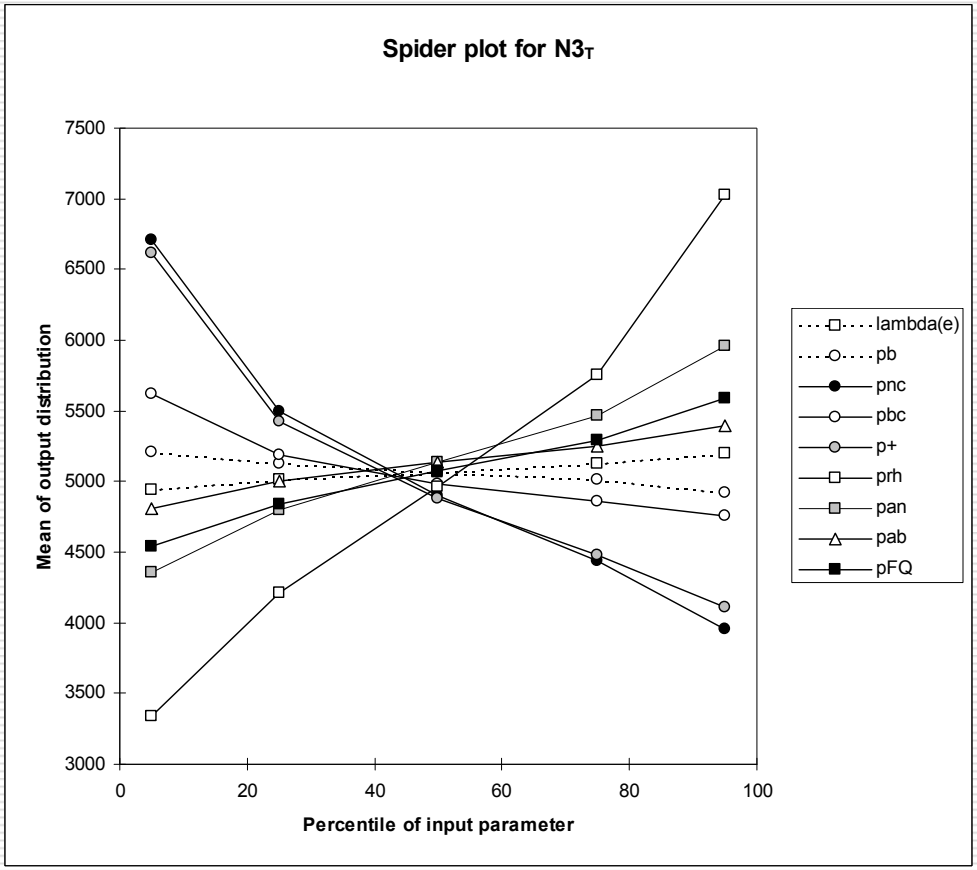
Variability and uncertainty of Simulation Inputs

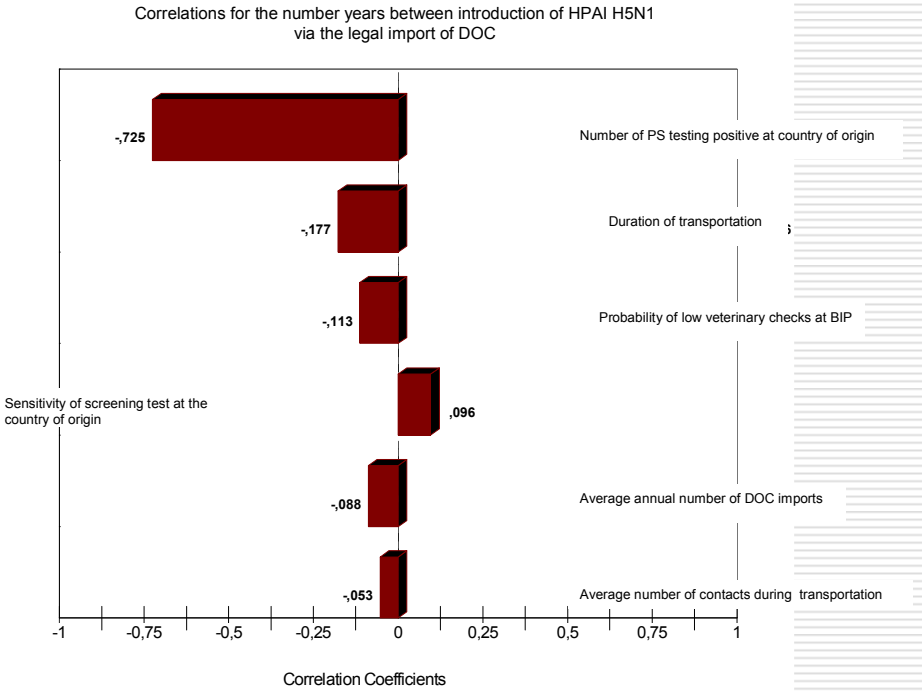
- "Variability is a phenomenon in the physical world to be measured, analysed and where appropriate explained. By contrast, uncertainty is an aspect of knowledge." (Sir David Cox)
- Variability is a function of the system and is the effect of chance; cannot be reduced – aleatory uncertainty
- Uncertainty is a function of the assessor; can be reduced – epistemic uncertainty
- Both represent the unpredictability of the system – total uncertainty

Analysing the uncertainty

- We can use tornado plots (and other graphing techniques) to determine key uncertainties in our model – parameters that are influential.
- This helps focus on future data needs
- Doesn’t tell us sensitivity to:
  - Model assumptions
  - Inappropriateness of data

Showing key uncertainties - Tornado charts Spider plot





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Sensitivity testing

- Your outputs will be constructed in terms of a number of interrelated variables.
- Ex: probability to import disease will depend on prevalence, Se and Sp or test, number of animals imported…
- You need to determine which variable has the most influence in the output = Sensitivity testing
- Highlight the key points in your analysis

Sensitivity analysis – key aspects

- A filtering technique
- **Worst case scenario** used to filter out whether worth worrying about
- **Best case scenario** as preliminary filter on risk management options
  - Risk manager can discount options where most optimistic benefits does not justify its cost.
  - Avoid exaggerating the extreme scenario beyond what is feasible.
- **What-if scenarios**
  - Where quantified uncertainty about parameter, a value is used that gives the required extreme, like 1 percentile, or 99 percentile.

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Ensure clarity / Feedback

- Transparency
- Referenced
- Circulation of the model for discussion and constructive criticism

Evaluation of risk model – key questions:

1. **Does the risk assessment answer clearly to the defined risk question?**
2. **Is the response useful?**
3. **What are the data gaps?**
4. **What modeling techniques (statistics, distributions, methods of calculation) did they use?**
5. **Did they report key assumptions of the risk pathway parameters?**
6. **Did they perform a sensitivity analysis? How?**
7. **How would you rate the analysis? Would you be confident to use it to make decisions? Were they hiding anything?**

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Report available at: http://www.ifpri.org/sites/default/files/publications/hpaiwp21_ethiopia.pdf

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