What is needed to get Bayesian Networks robust to weaknesses in knowledge?

Ullrika Sahlin, Centre of Environmental and Climate Research

Lund University, Sweden

Ullrika.Sahlin@cec.lu.se

http://www.cec.lu.se/ullrika-sahlin

Abstract

Also the sun has its spots.

Bayesian Networks are useful, but has its limitations.

I will mention some problems with BNs coming from weaknesses in knowledge.

Instead of leaving you in total misery - I will end with some suggestions on how to deal with these issues without totally abandoning Bayesian Networks.
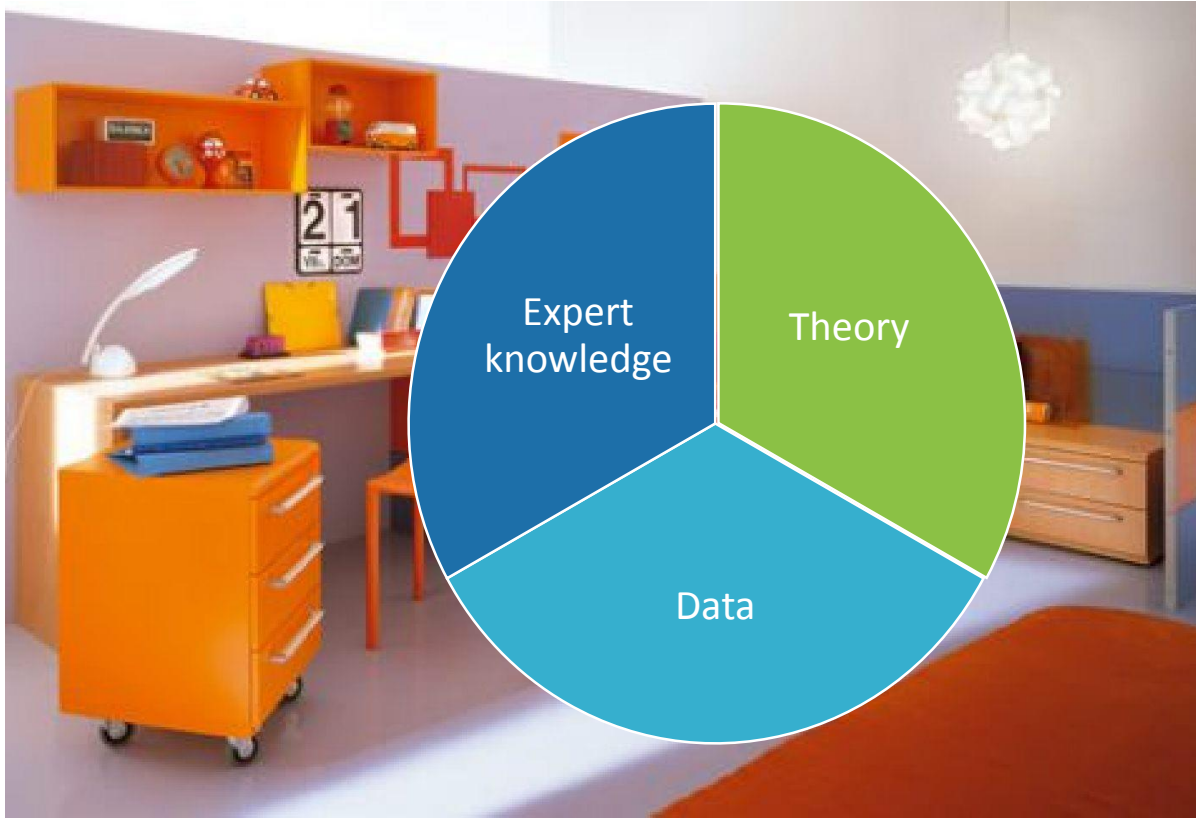
Things are seldom ideal…

Five-year-old Harry Bateman, won a prize for having the messiest bedroom in the UK. Daily Mail

Things are seldom ideal in risk analysis

Expert knowledge

Theory

Data

© Time4Sleep.co.uk

Five-year-old Harry Bateman, won a prize for having the messiest bedroom in the UK. Daily Mail

LUND UNIVERSITY

Things are seldom ideal in risk analysis

Expert knowledge

Theory

Data

© Time4Sleep.co.uk
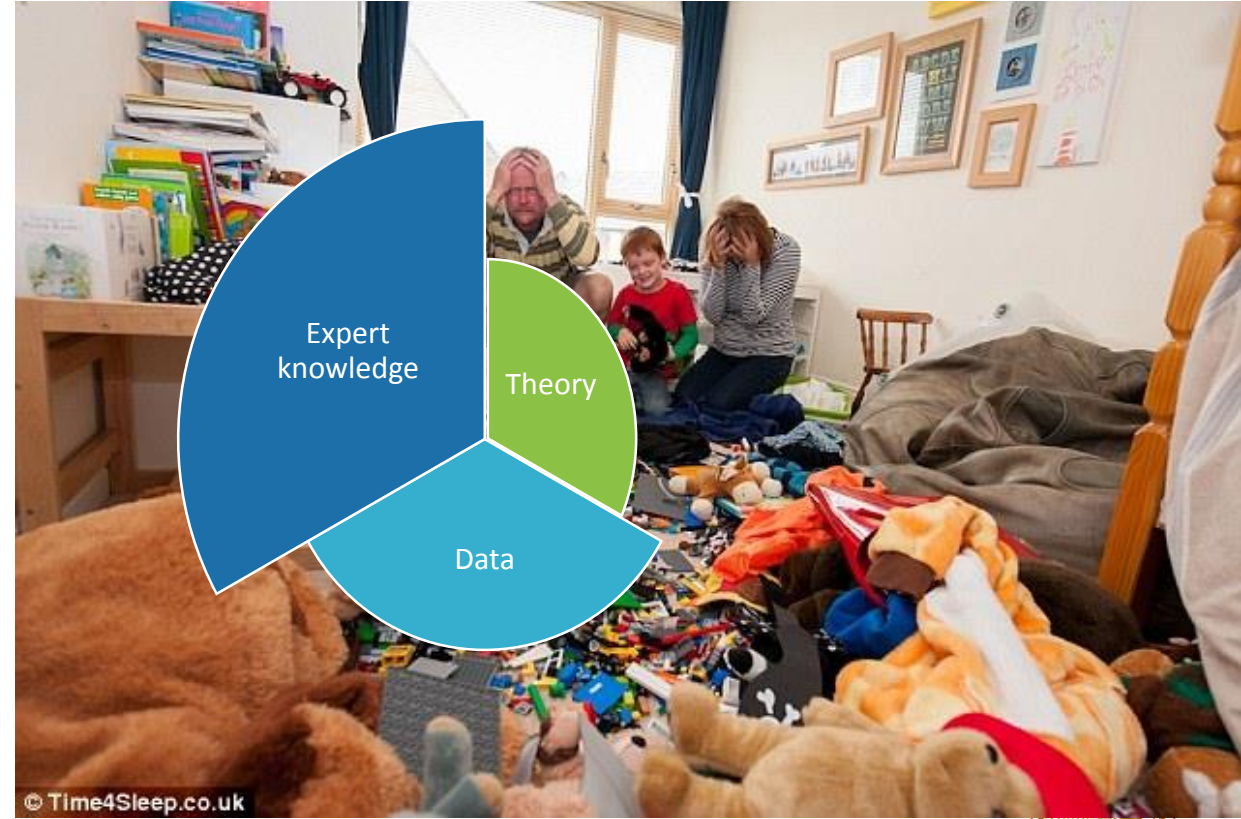
Five-year-old Harry Bateman, won a prize for having the messiest bedroom in the UK. Daily Mail

A structured approach to manage uncertainty

Should adapt quantification of uncertainty to the:

- Characteristics of the decision problem, e.g. what we need to know to answer the assessment question

- Characteristics of the knowledge-bases, including strength in knowledge

U = P　　　　　**U = ?**

Weakness in knowledge

A structured approach to manage uncertainty

- Adapt quantification of uncertainty

  = a decision problem

- Why should we care about this decision?

- What is a good How do we know what the strength in knowledge is and what modifications that are required?

U = P
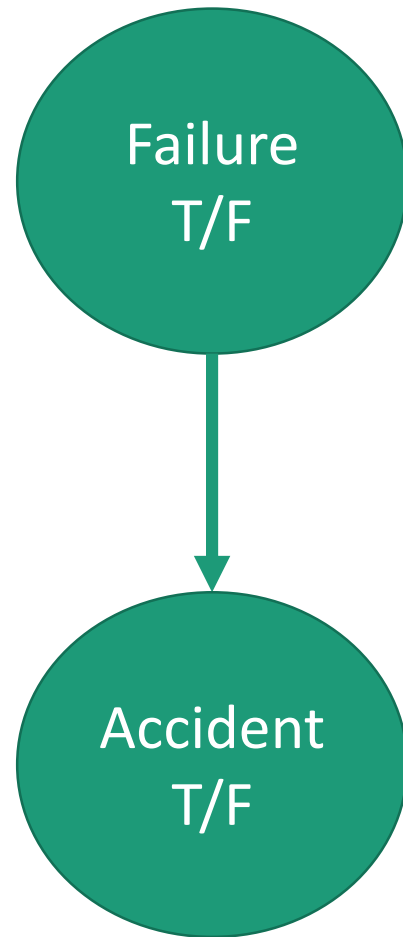
U = ?

Weakness in knowledge

A view on uncertainty in BNs

- Bayesian Networks are probabilistic causal models
- BNs enable forward simulation (forecasting) and backward simulation (learning, inverse modelling)
- BN quantify uncertainty by probability
- Ideally, probability in a BN represent either relative frequencies for aleatory uncertainty (variability) or personal probabilities (beliefs) for epistemic uncertainty, but not both at the same time

Failure T/F

Accident T/F
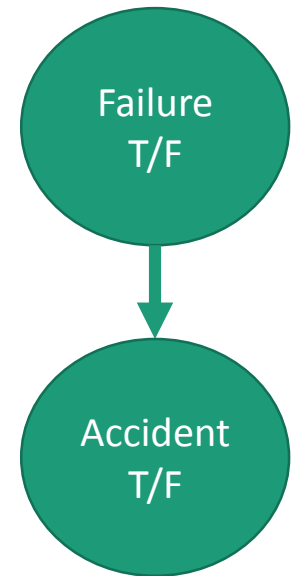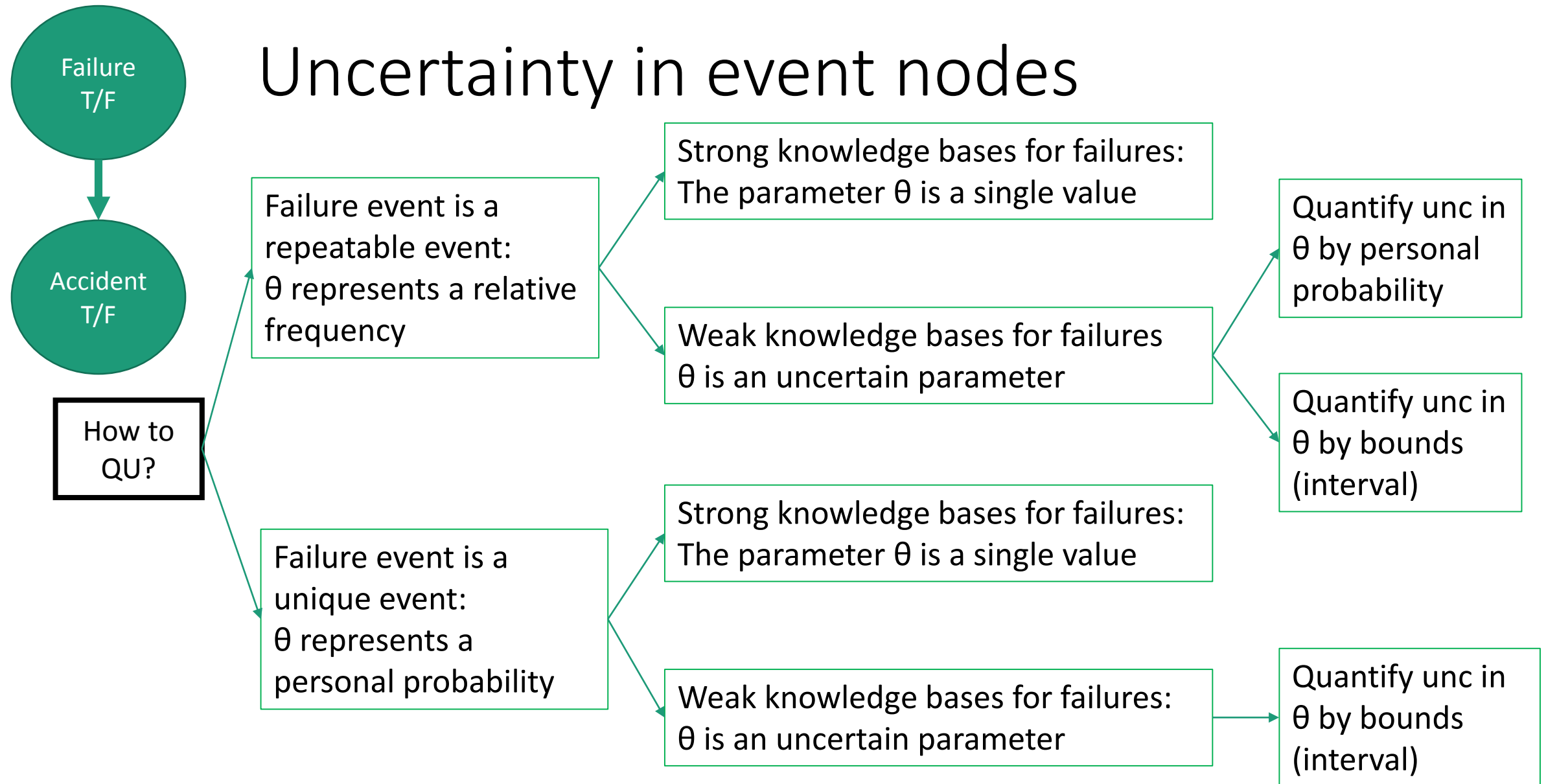
Uncertainty in event nodes

θ is the failure probability

How to Quantify Uncertainty in θ?

Uncertainty in event nodes

Failure T/F

Accident T/F

How to QU?

Failure event is a repeatable event:
θ represents a relative frequency

Failure event is a unique event:
θ represents a personal probability

Strong knowledge bases for failures:
The parameter θ is a single value

Weak knowledge bases for failures
θ is an uncertain parameter

Strong knowledge bases for failures:
The parameter θ is a single value

Weak knowledge bases for failures:
θ is an uncertain parameter

Quantify unc in θ by personal probability

Quantify unc in θ by bounds (interval)

Quantify unc in θ by bounds (interval)

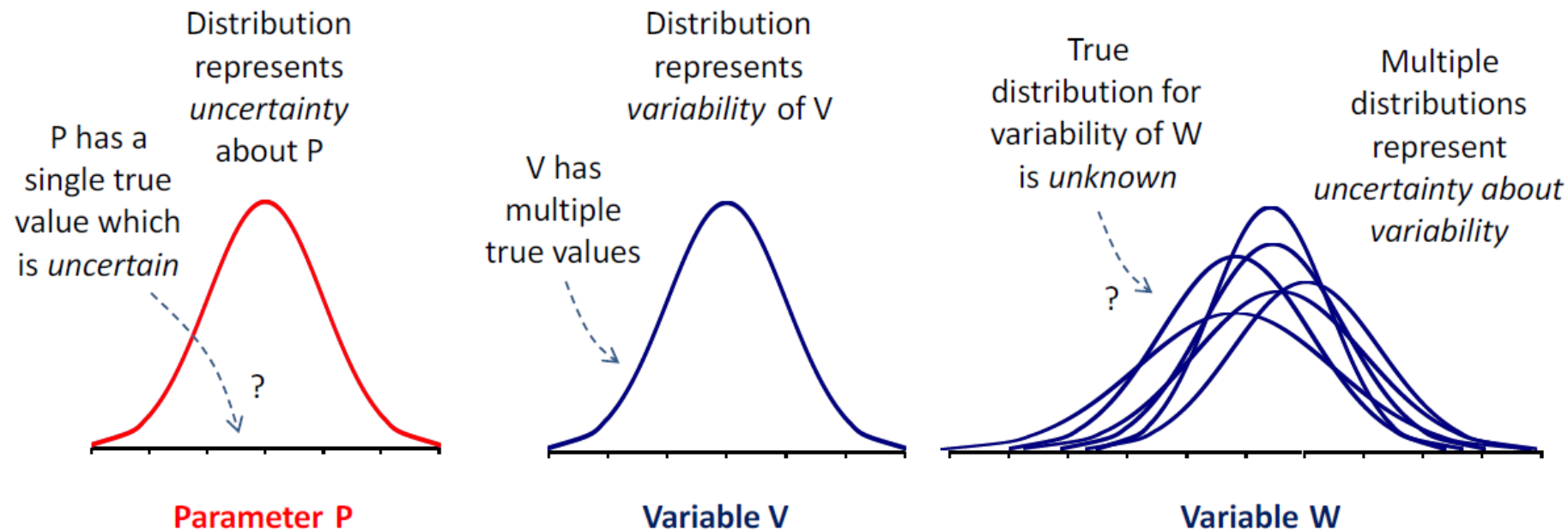# Uncertainty in continous nodes (variables)

Figure 2: Illustration of the distinction between uncertainty and variability (left and central graphs), and that both can affect the same quantity (right hand graph).

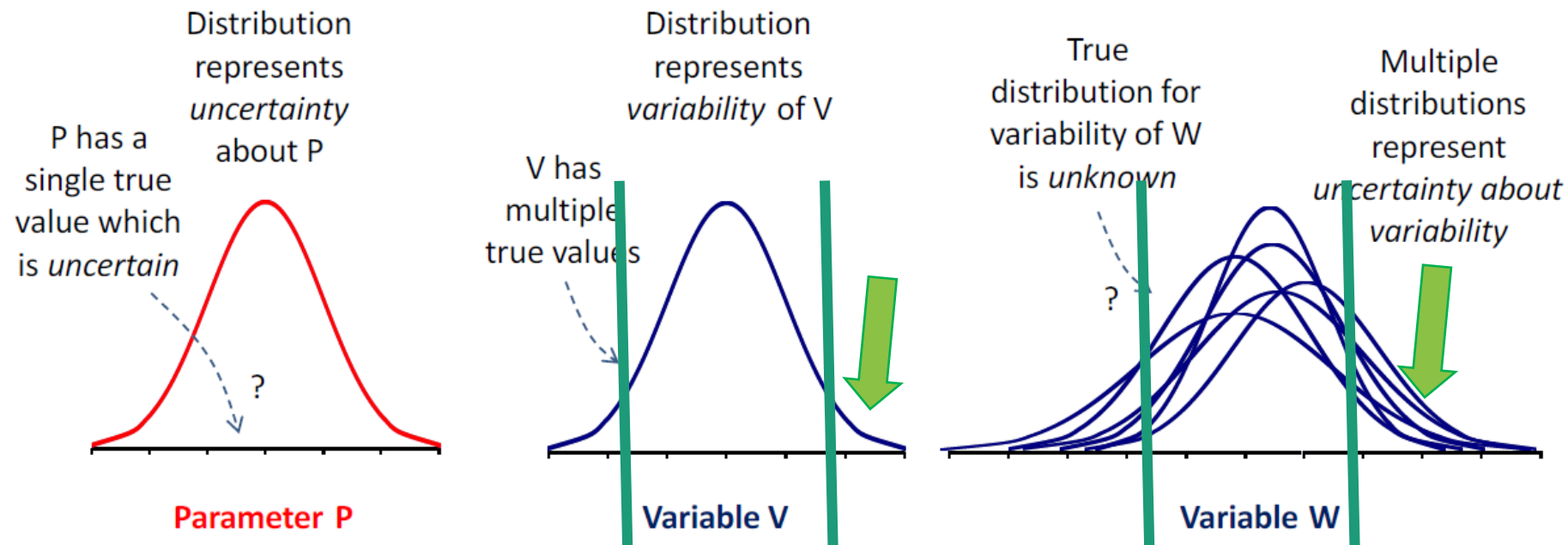# Uncertainty in continous nodes (variables)
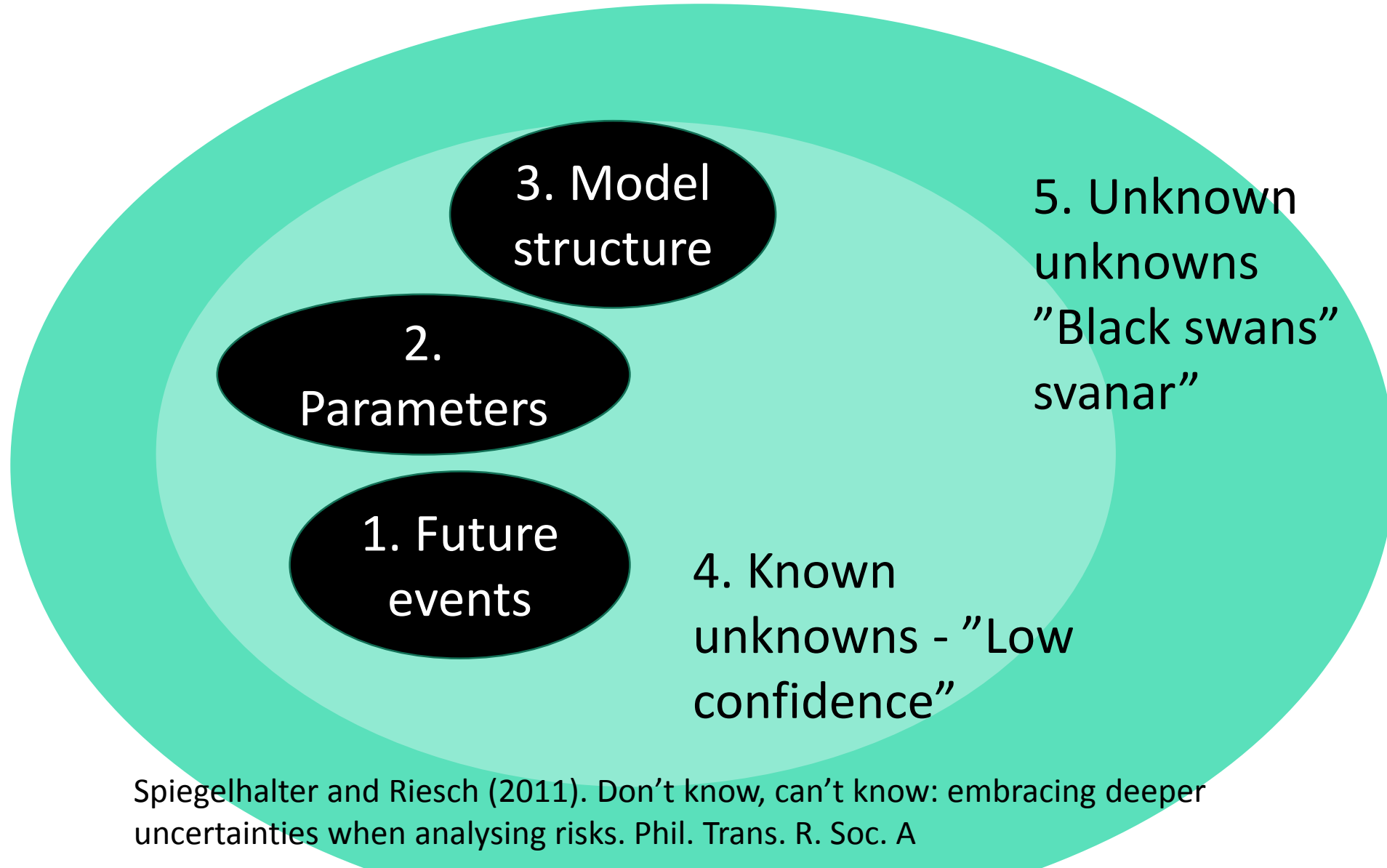

Figure 2: Illustration of the distinction between uncertainty and variability (left and central graphs), and that both can affect the same quantity (right hand graph).

Where do uncertianty come from?

3. Model structure

2. Parameters

1. Future events

5. Unknown unknowns "Black swans" svanar"

4. Known unknowns - "Low confidence"

Spiegelhalter and Riesch (2011). Don't know, can't know: embracing deeper uncertainties when analysing risks. Phil. Trans. R. Soc. A

Sources, types and location of uncertainty

- Substantive – Knowledge
    - Parameters
    - Network sturcture

    - Data quality (measurment errors, partial observability, poor study design etc)
    - Experts Knowledge (bias and heuristicts)
    - Extrapolation
    - Scenario based analysis
- Procedural
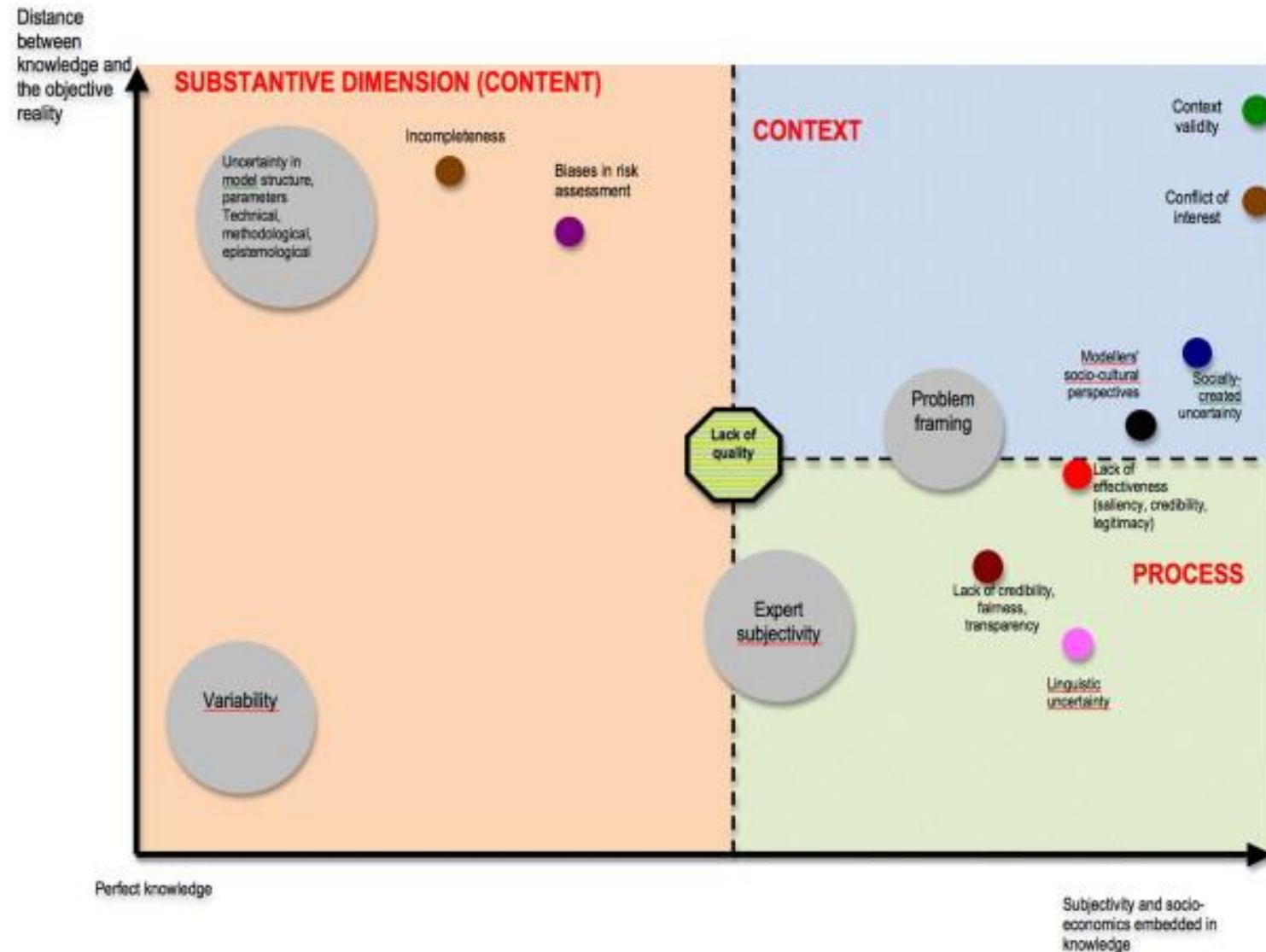- Contextual

Uncertainty in the knowledge production process

Fig. 1. Representations of several locations and sources of "problematic knowledge" in the literature.

Maxim and van der Sluijs (2011)

Questions

- What is a good decision on how to manage uncertainty in a risk assessment?

- What is the level of weakness in my current knowledge?

- Is this something that decision makers care about?

- Will it generate better decisions?

U = P   **U = ?**

Weakness in knowledge

What to do with your BN going weak?

Strong knowledge/Low level of uncertainty

- *ideal problem*
- Perfectly ok to use a Basic BN with decision nodes, utility nodes and state nodes

Medium strong knowledge/Intermediate level of uncertainty

- *problem where sources of uncertainty and uncertainty in outputs can be quantified*
- Expand the model with more uncertainty quantified by probability or as intervals on probability
- Software for such BNs, e.g. credal networks?

What to do with your BN going weak?

Weak knowledge/High level of uncertainty

- *problem where there are sources of uncertainty not quantified but still relevant to take into account*

- Some sources of uncertainty is not quantified by probabilities or non-probabilistic intervals.

- Sensitivity analysis towards changes in the non-quantified sources of uncertainty on uncertainty in what matters to the decision makers

- Scenario based assessment – apply the BN on different scenarios and the results in each scenario is noted without being integrated.

Also, suggest decision criteria!

U = P   **U = ?**

Weakness in knowledge

Expectation → Regret → Satisficing

LUND UNIVERSITY

Measures of robustness

DEEP UNC

Regret-Based

R1. Deviation from baseline state of the world

R2. Deviation from "best" solution in each state of the world

Satisficing-Based

S1. Fraction of states in which solution meets criteria

S2. Uncertainty horizon before any state of the world violates criteria

Expectation-Based

E?

$$\bar{E} - \underline{E}$$

Herman et al (2015)