Overcoming barriers to incorporating uncertainty in LCA

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Barriers to incorporating uncertainty in LCA

1. There is limited guidance on how to conduct an uncertainty analysis

2. Characterizing uncertainty is difficult

3. People have a hard time processing outcomes of uncertainty analyses

Strategies for overcoming these barriers

1. There is limited guidance on how to conduct an uncertainty analysis

LCA community works to establish more detailed guidance

2. Characterizing uncertainty is difficult

a) Develop more prescriptive uncertainty characterization guidance,
b) expand uncertainty in LCIs databases, c) underspecify uncertainty

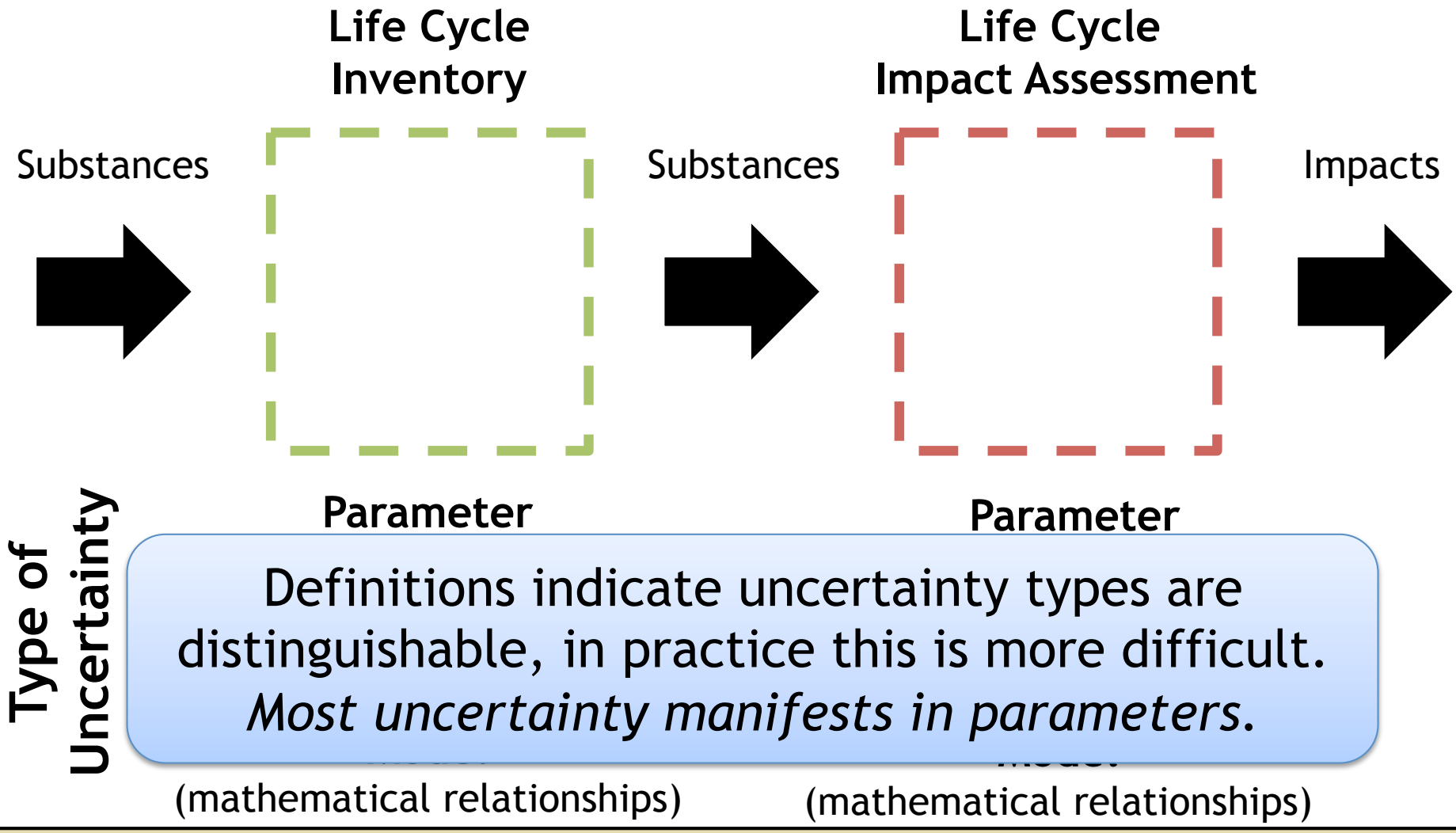
3. People have a hard time processing outcomes of uncertainty analyses

Mandatory statistics courses at all levels of school?!?!
More education about uncertainty, or embedded within analyses

1. There is limited guidance on how to conduct an uncertainty analysis

A proposed methodology for uncertainty analysis in comparative assessments

Typical uncertainty framework for LCA



Key LCA uncertainty quantities

Uncertainty Quantity	Description	Example
Empirical quantity	Measurable (in principle) with a *true* value	Electricity consumption, particulate emissions
Model domain parameter	Define scope of system with an *appropriate* value	Temporal or geographic boundaries
Value parameter	Represent aspects of the preferences of the analyst with an *appropriate* value	Discount rate, allocation factor

Others include decision variables and outcome criterion (LCIA metrics)

Morgan and Henrion 1990

Method for uncertainty analysis in comparative assessments

Iterative process

Process Step	Goals of Analysis
1. Parameter triage: coarse-level probabilistic analysis	Determine which values are highest priority for further refinement based on their influence on the result.
2. Refined parametric and probabilistic analysis	Comment on robustness of differences among alternatives given uncertainty in parameters across a range of scenarios. Comment on scenario characteristics that have the most influence on robustness.

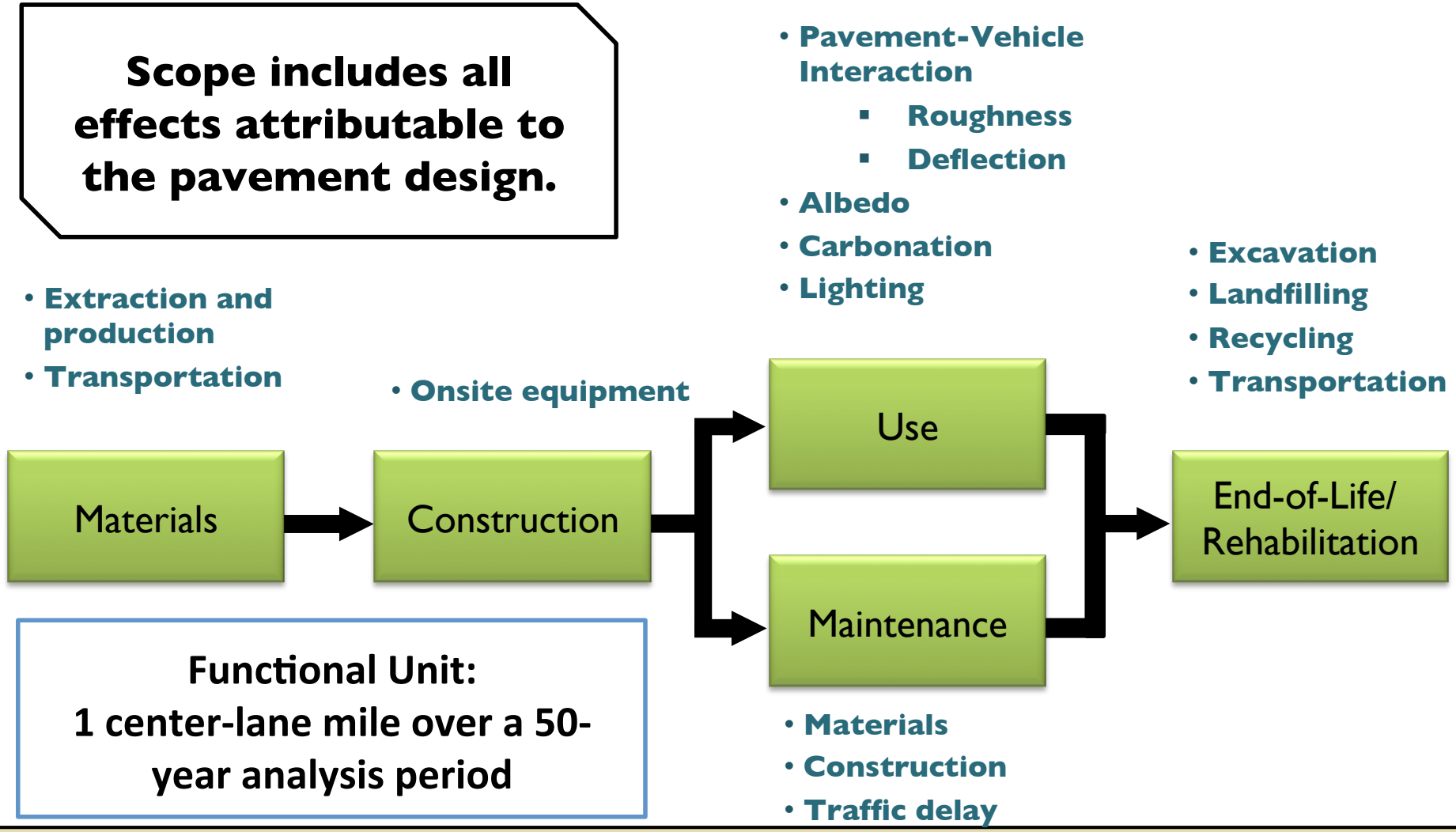
Uncertainty characterization

	Empirical quantities	Value and model domain parameters
1. Parameter triage: coarse-level probabilistic analysis	• **Probabilistic** characterization of all model and inventory parameters, OR • **Rough** characterization for parameters that have no clear representative value and/or distribution.	Broad range of **discrete** values or continuous values with equal likelihood (i.e., uniform distribution).
2. Refined parametric and probabilistic analysis	For influential parameters: • Obtain more **detailed** probabilistic distribution, OR • **Parameterize** using a range of values.	• For influential parameters, **refine** range of values. • May treat some values probabilistically.

Case study: pavements

Scope of case study

Scope includes all effects attributable to the pavement design.

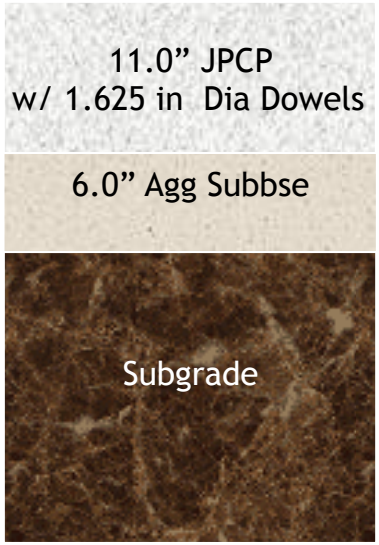


Functional Unit:
1 center-lane mile over a 50-year analysis period

Case study: dry freeze urban interstate HW in Missouri

Design A

Design C



Parameter	Value
AADTT two Directions	8,000 vehicles/ day
Number of Total Lanes-two Directions	6
AADTT Linear Annual Increase	3%
Climate	Wet Freeze - MO
Soil Type	A-7-6

Designs were developed by an independent pavement design firm

Two maintenance and rehabilitation scenario:

- Agency-based maintenance and rehabilitation
- Mechanistic-based maintenance and rehabilitation

Examples of uncertain parameters in pavement LCA

Input Name	Type	Uncertainty representation
Roughness prediction (reliability level)	Value parameter	Discrete uniform
Scope: Salvage Life	Model domain	Binary
Cement impact	Empirical	Lognormal
Traffic growth factor	Empirical	Lognormal
Maintenance and rehabilitation	Model domain	Discrete uniform

Method for uncertainty analysis in comparative assessment

Process Step	Goals of Analysis
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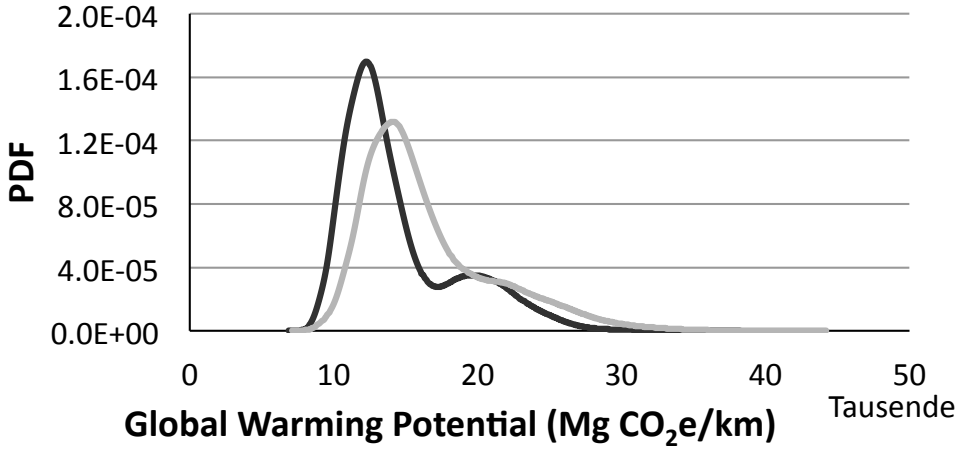
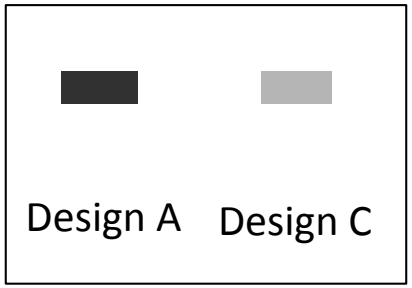
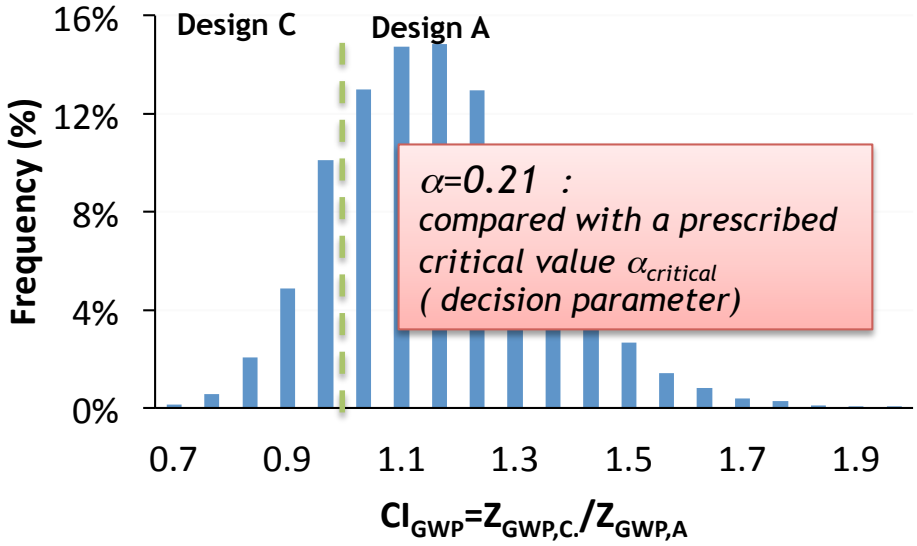
Metric of comparison:
Is the difference statistically significant?





α% of the time design C has lower impact

- Characterizing the level of confidence
- Incorporating correlation for a fair comparison

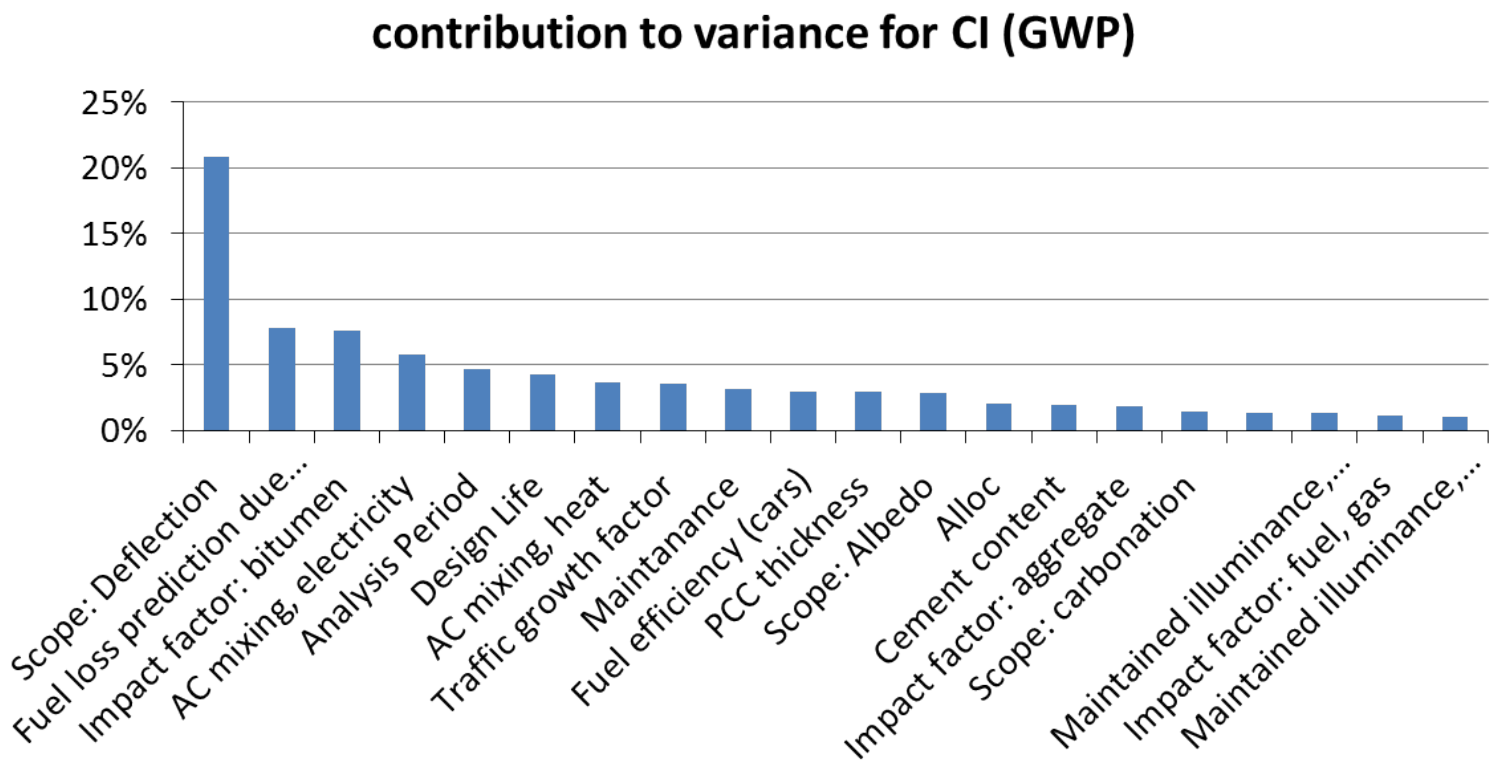


Comparison indicator : *

* Huijbregts (2003)

Sensitivity analysis:
What are the key drivers of performance?

Contribution to variance for the difference in overall impact



Measure of sensitivity :
Spearman partial rank correlation

Method for uncertainty analysis in comparative assessment

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Refined Parametric Analysis (Scenarios)

- Scenario space is discretized based on nine parameters:
  - Having higher ranking in the sensitivity analysis: Hot spot
  - Parameters of interest to stakeholders: Hot button
- A combination of parametric and probabilistic analysis is conducted

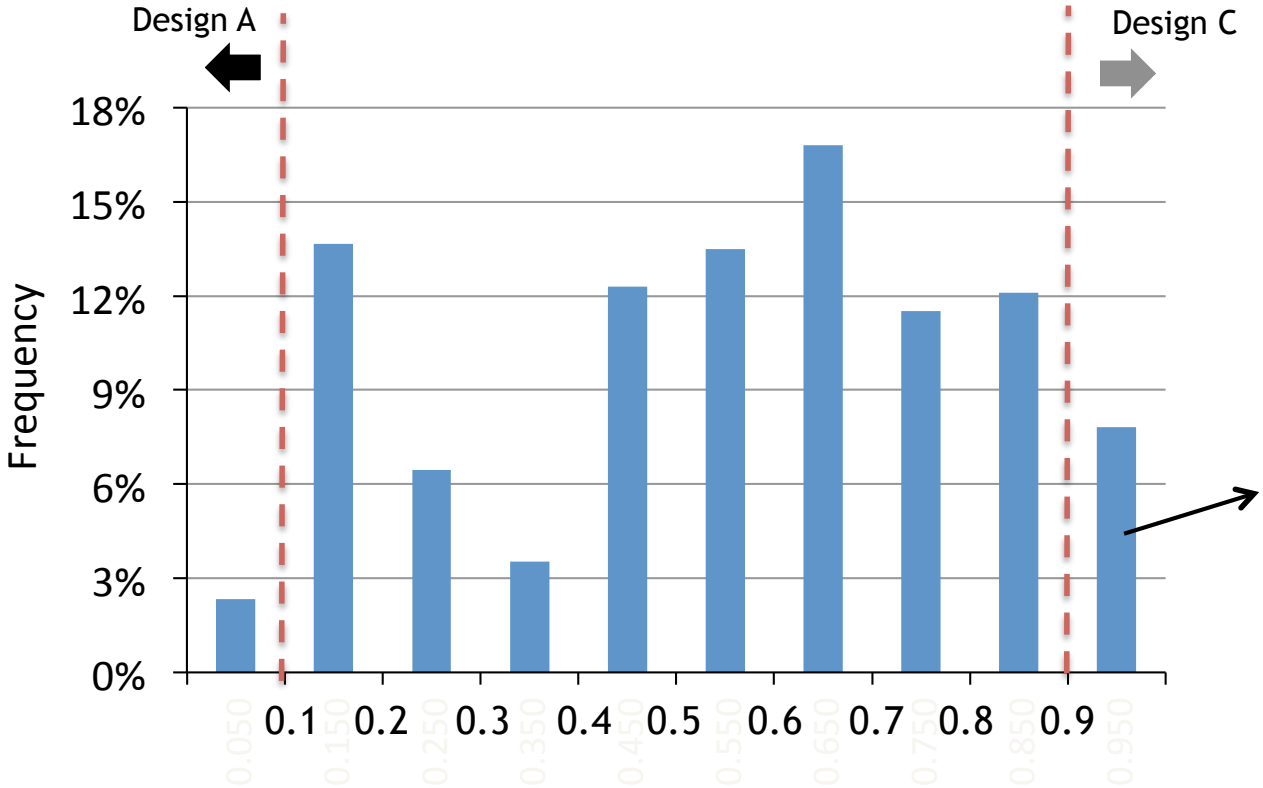
Design life	Analysis period	M & R	Salvage	Scope: IRI	Scope: Deflection	Scope: Albedo	IRI: prediction	Impact factor: Bitumen
20	50	DOT	No	No	No	No	0.50	0.25
30	75	MEPDG	Yes	Yes	Yes	Yes	0.95	0.55

- Quantity of interest
  - Comparison indicator

$$CI_{GWP} = \frac{Z_{GWP_B}}{Z_{GWP_A}} \qquad \alpha = P(CI_{GWP} < 1)$$

Summary of scenario analysis

Variation of quantity of interest across the scenario space



$$\alpha = P(CI_{GWP} < 1)$$

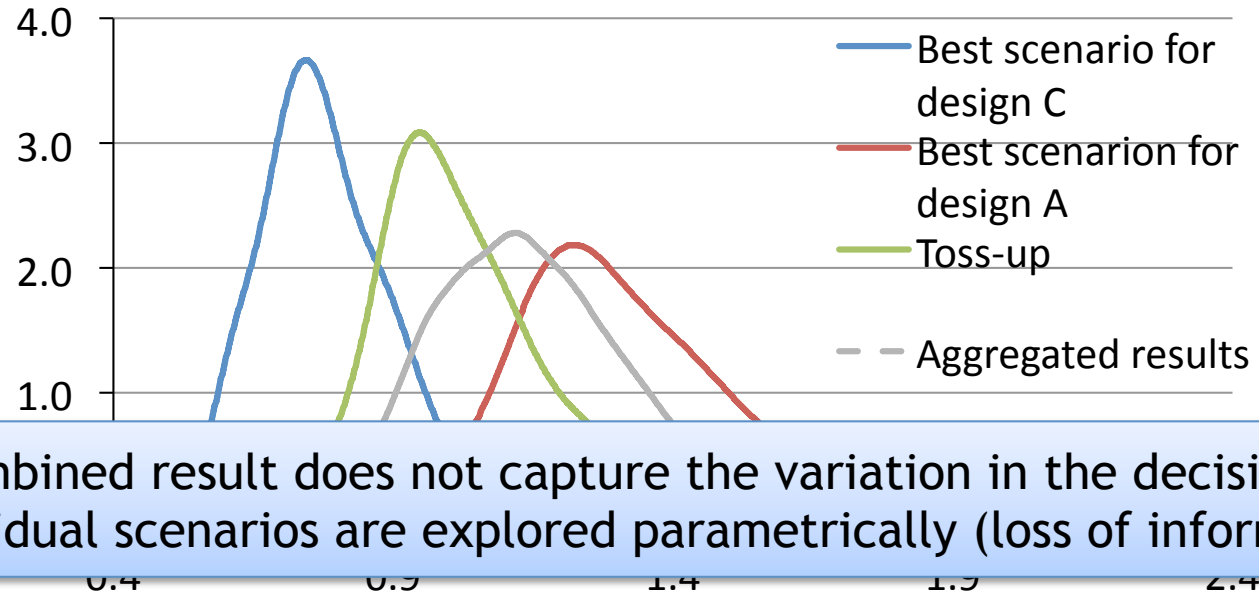
Set decision threshold:

$\alpha_{critical} = 0.9$

e.g., In 8% of scenarios design C has lower impact than design A

Resolving the difference

Scenarios	a=P(CI<1)	Design life	Analysis period	M &R	Salvage	Scope: IRI	Scope: Deflection	Scope: Albedo	IRI: Prediction	Impact: Bitumen
Best C	0.97	30	50	1	0	NO	Yes	No	0.5	0.55
Best A	0.065	20	70	0	1	Yes	Yes	No	0.5	0.25
Toss-up	0.50	30	50	0	1	Yes	No	No	0.95	0.25



The combined result does not capture the variation in the decision when the individual scenarios are explored parametrically (loss of information)

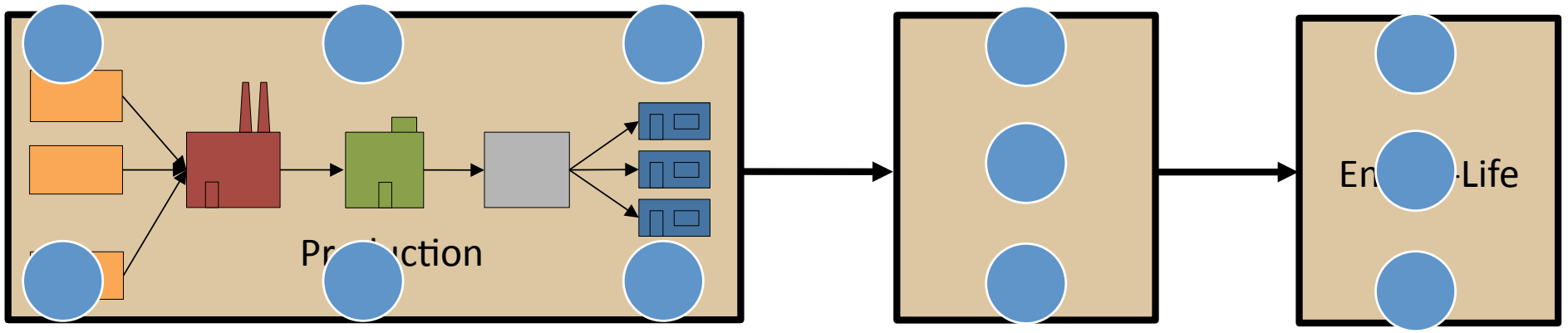
1. There is limited guidance on how to conduct an uncertainty analysis

- More prescriptive guidance on uncertainty analysis is needed
- We propose:
  - Eliminating parameter/scenario uncertainty distinction
  - Conducting parameter triage followed by refined parametric analysis
  - Performing combined parametric and probabilistic analyses

2. Characterizing uncertainty is difficult

Probabilistic underspecification as a means of streamlining LCA

Underspecification as part of initial triage step



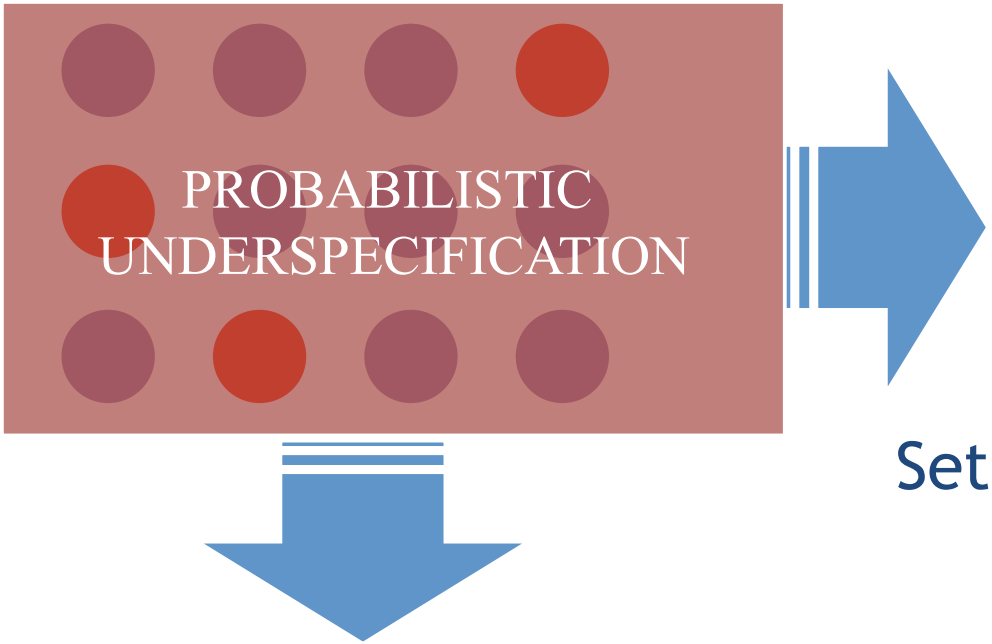
Use surrogate data to roughly characterize "all" activities

Low fidelity

High uncertainty

Basic Triage Concept:
Identify and refine set of interest

Bill of Activities (BOA)



Further Specified

Set of Interest (SOI)

Left Underspecified

Estimating Uncertainty of Low Fidelity BOA:

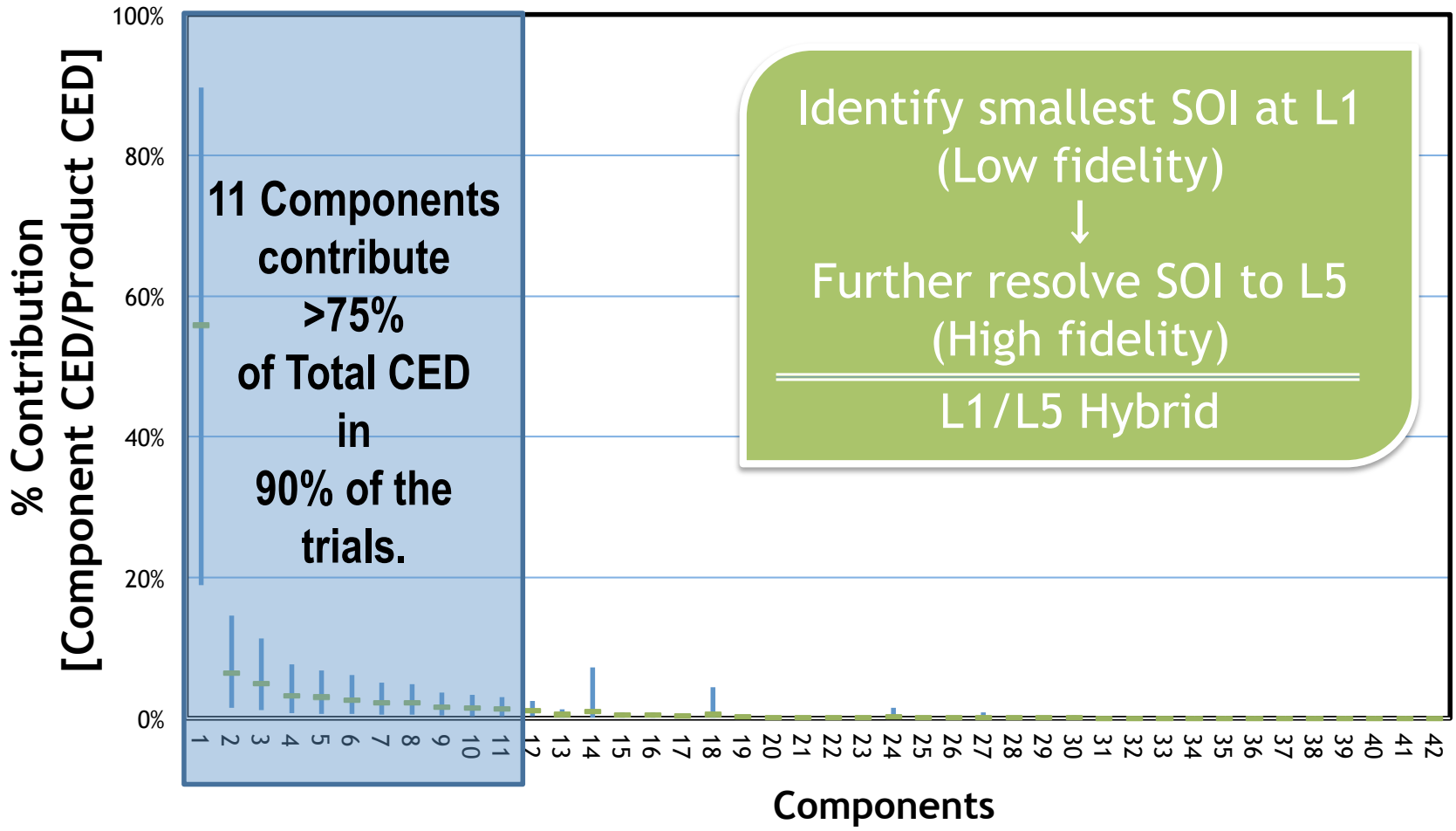
Implementing Underspecification for Materials Impact

Level 1	Level 2	Level 3	Level4	Level 5	CED	STDEV
Metal	Ferrous metals	Iron	Iron cast	Cast iron, at plant/RER U	25	3
				Iron, sand casted/US	29	3
			Iron4	Ferrite, at plant/GLO U	10	1
				Iron and steel, production mix/US	27	3
			Iron pig	Pig iron, at plant/GLO U	23	3
			Iron scrap	Iron scrap, at plant/RER U	0.7	0.08
		Steel	Steel chromium	Chromium steel 18/8, at plant/RER U	772	9
				Steel, electric, chromium steel 18/8, at plant/RER U	0.06	0.008
				Steel, converter, chromium steel 18/8, at plant/RER U	30	4
			Steel sheet	Cold rolled sheet, steel, at plant/RNA	26	3
				Galvanized steel sheet, at plant/RNA	23	3
				Hot rolled sheet, steel, at plant/RNA	27	3
			Steel coil	Stainless steel hot rolled coil, annealed & pickled, elec. arc furnace route, prod. mix, grade 304 RER S	10	1
				Steel hot rolled coil, blast furnace route, prod. mix, thickness 2-7 mm, width 600-2100 mm RER S	12	1
			Steel unalloyed	Steel, electric, un- and low-alloyed, at plant/RER U	11	1
				Steel, converter, unalloyed, at plant/RER U	74	9
			Steel low alloyed	Steel, converter, low-alloyed, at plant/RER U	31	4
				Steel, low-alloyed, at plant/RER U	23	3
			Steel reinforcement	Reinforcing steel, at plant/RER U	69	8
			Steel section	Steel hot rolled section, blast furnace and electric arc furnace route, production mix, at plant GLO S	9	1
			Steel rebar	Steel rebar, blast furnace and electric arc furnace route, production mix, at plant GLO S	28	3
			Steel tin plated	Tin plated chromium steel sheet, 2 mm, at plant/RER U	1430	171
	Non-Ferrous metals	Aluminum	Aluminum shaped	Aluminium extrusion profile, primary prod., prod. mix, aluminium semi-finished extrusion product RER S	44	5
				Aluminium sheet, primary prod., prod. mix, aluminium semi-finished sheet product RER S	57	7
			Aluminum primary	Aluminium, primary, at plant/RER U	195	23
				Aluminium, primary, liquid, at plant/RER U	190	23
				Aluminum, primary, ingot, at plant/RNA	148	18
				Aluminum, primary, smelt, at plant/RNA	143	17

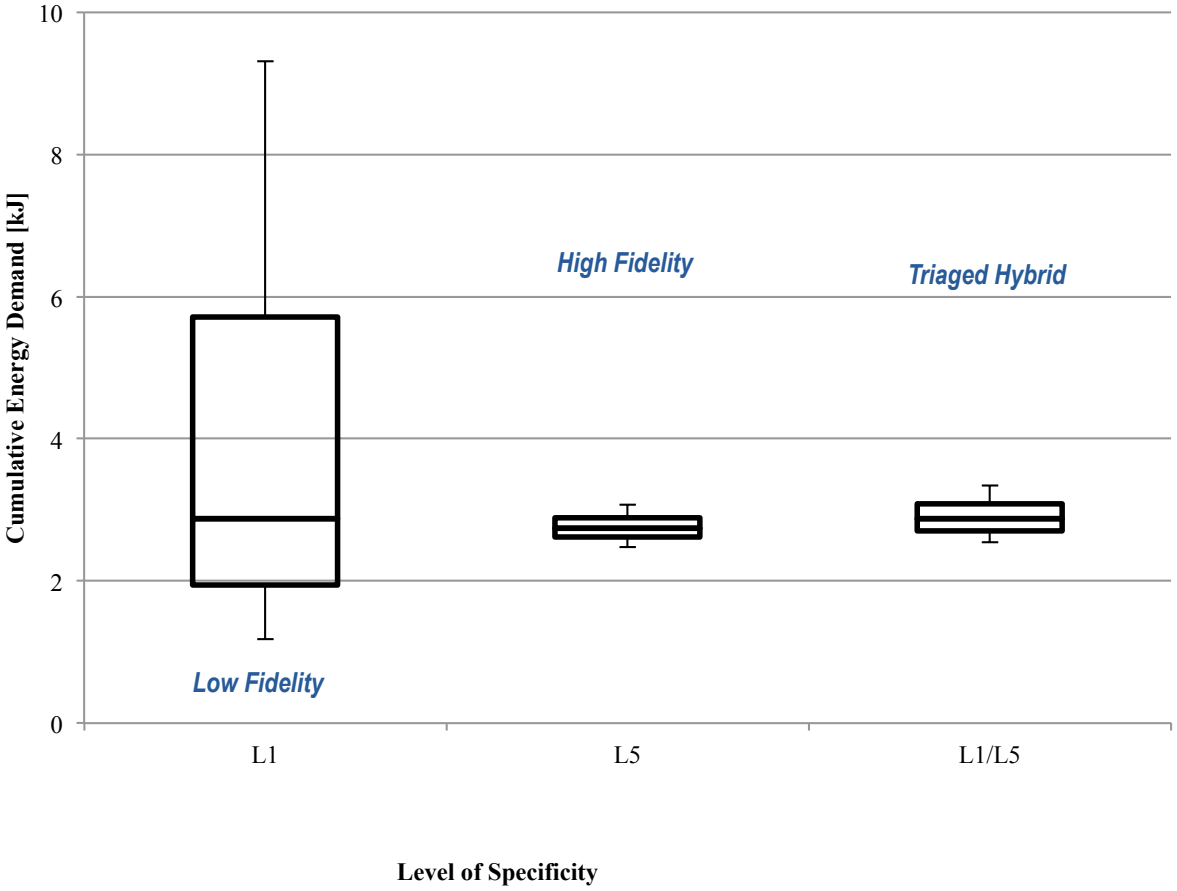
Galvanized steel, at plant/RNA

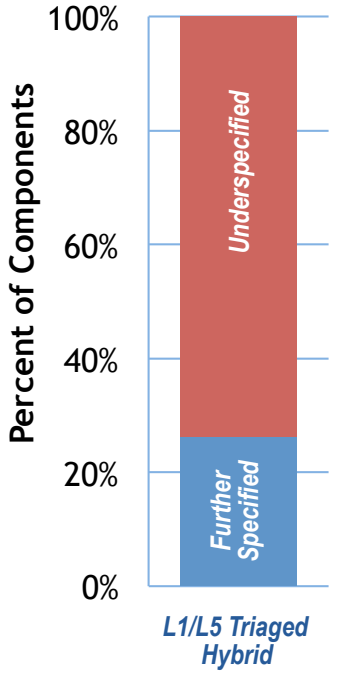
Identifying Set of Interest(SOI)

Low Fidelity (L1) Analysis (highly underspecified)



Results of Simple Case Study:
Effective (near hi-fi result); Efficient (24% of BOM)

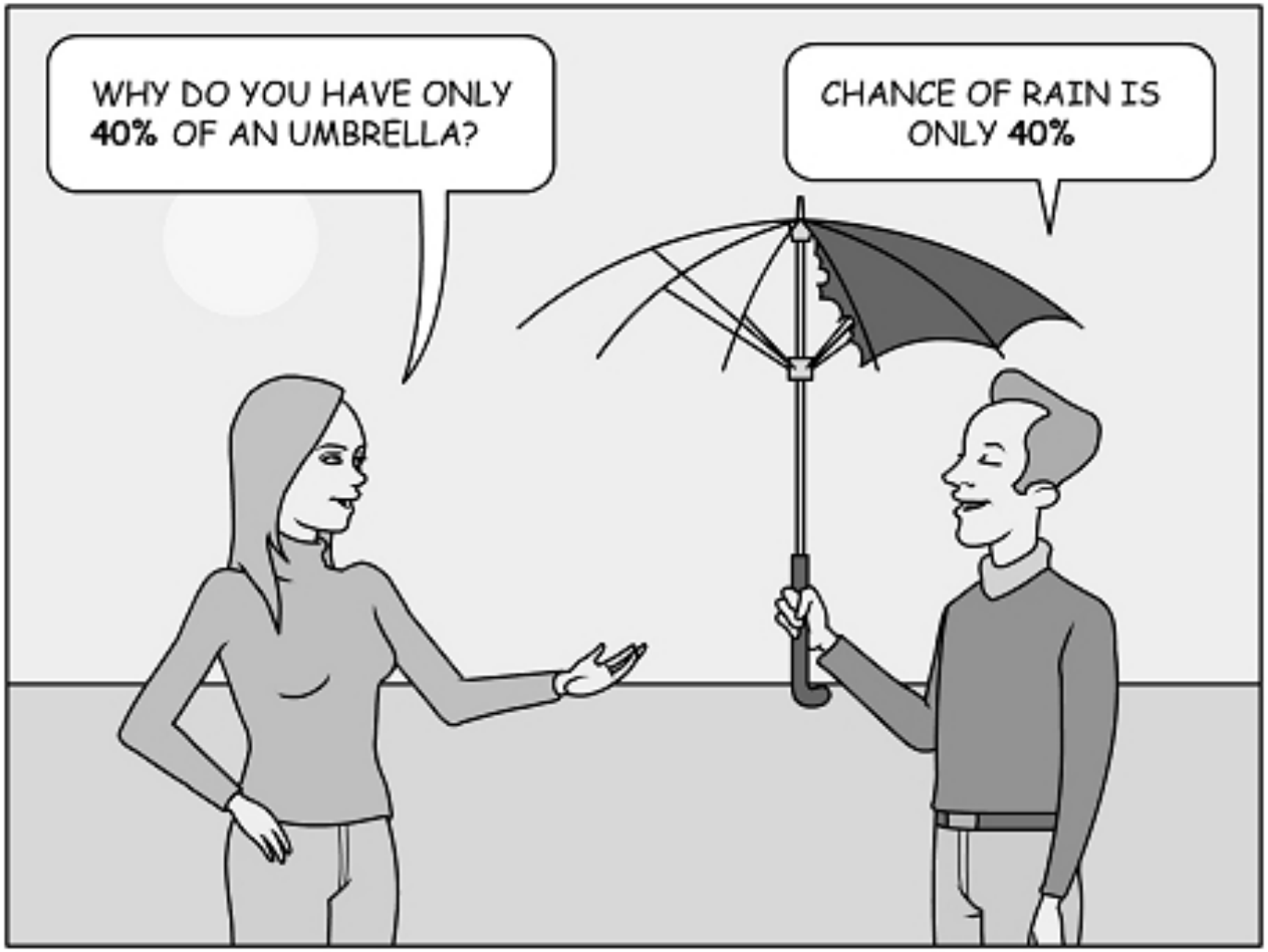




2. Characterizing uncertainty is difficult

- Detailed uncertainty characterization is unnecessary for the majority of inventory data
- Probabilistic underspecification can be used to streamline uncertainty characterization
- This reduces data collection efforts for a bill of activities

3. People have a hard time processing outcomes of uncertainty analyses



Thank you

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