Consequential LCA and its consequences for LCA practice

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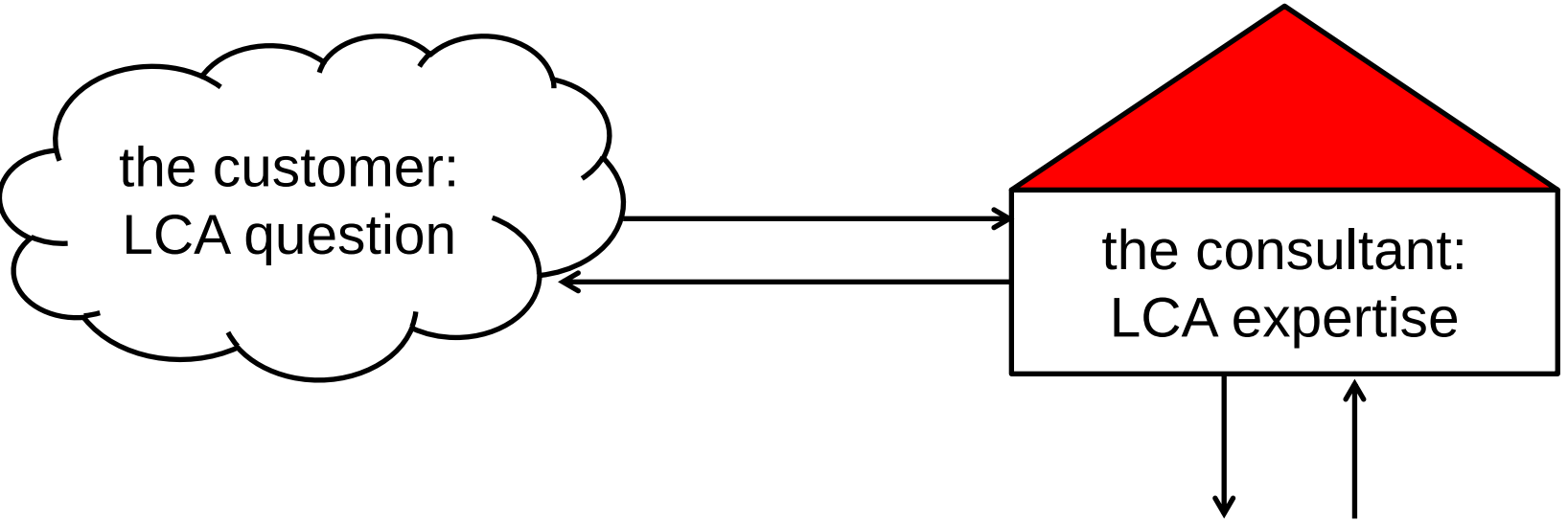
Requirements to do LCA

- Doing LCA from a practitioner's point of view



SimaPro

GaBi Software

Requirements to do LCA

- So, what do you need to do LCA?
  - 1: LCA question
  - 2: LCA software
  - 3. LCA expertise

Requirements to do ALCA/CLCA

- Reconsider this in the light of the ALCA/CLCA debate
- Is it still
  - 1: LCA question
  - 2: LCA software
  - 3. LCA expertise
- Or are there more/other steps?
- And which existing steps will change?

Requirements to do ALCA/CLCA

- 1. LCA question
- ALCA and CLCA answer different questions
  - ALCA: which impacts can be attributed to a product?
  - CLCA: what are the consequences of a change of products?

Decision support?		Kind of process-changes in background system / other systems	
		None or small-scale	Large-scale
	Yes	Situation A "Micro-level decision support"	Situation B "Meso/macro-level decision support"
	No	Situation C "Accounting" (with C1: including interactions with other systems, C2: excluding interactions with other systems)	

ILCD, General Guidance for Life Cycle Assessment - Detailed Guidance, 2011

Requirements to do ALCA/CLCA

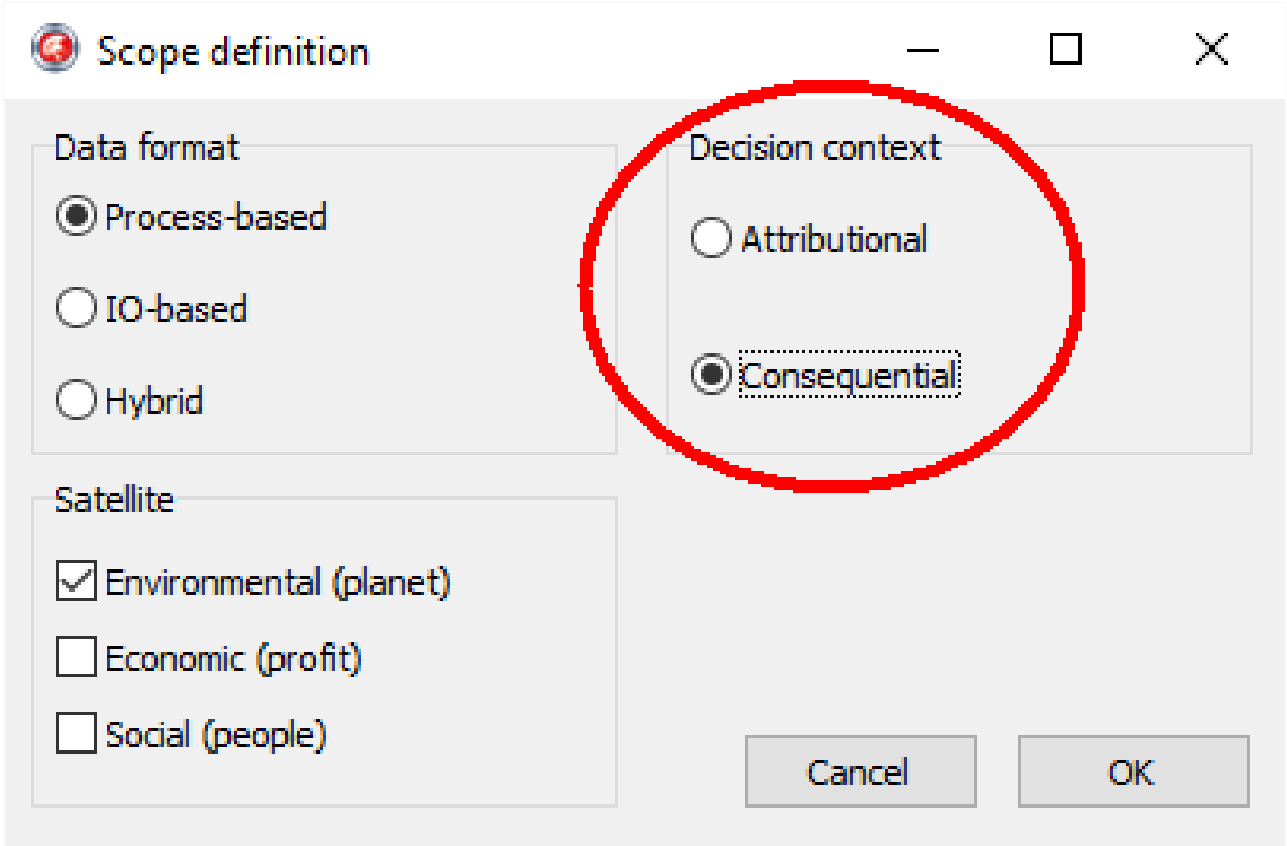
- 2. LCA software
- Let’s postpone this one for a while

Requirements to do ALCA/CLCA

- 3. LCA expertise
- Yes, we need to train our students/empolyees/ourselves to do ALCA, to do CLCA, and to choose when to do what
- A task for universities, UNEP/SETAC, ILCA, etc.

Requirements to do ALCA/CLCA

- 2. LCA software
- Is it just a question of adding a feature?



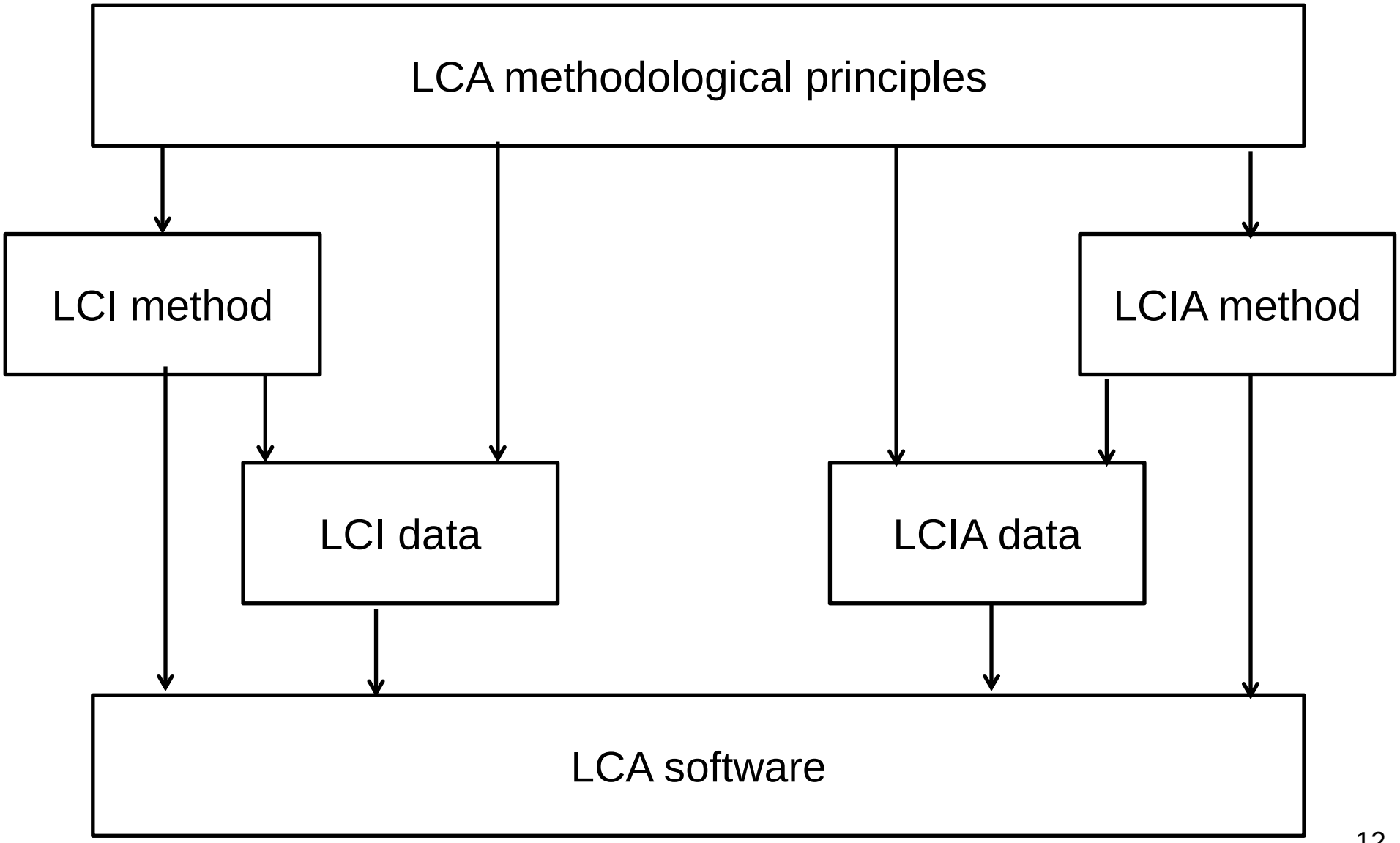
Requirements to do ALCA/CLCA

- But what is behind this new feature?
  - different methodological choices (partitioning vs. substitution)?
  - different databases (marginal vs. average)?
  - different data linkages (constrained vs. market mix)?
  - different calculation formulas ($\mathbf{BA}^{-1}\mathbf{f}$ or CGE)?
  - different impact assessment methods (CGWP vs AGWP)?
  - etc.

Requirements to do ALCA/CLCA

- So we subdivide
  - 2. LCA software
- into
  - 2a. LCA method
  - 2b. LCI data
  - 2c. LCIA methods
  - 2d. LCA software
- Let’s see

Methodology, method, data and software

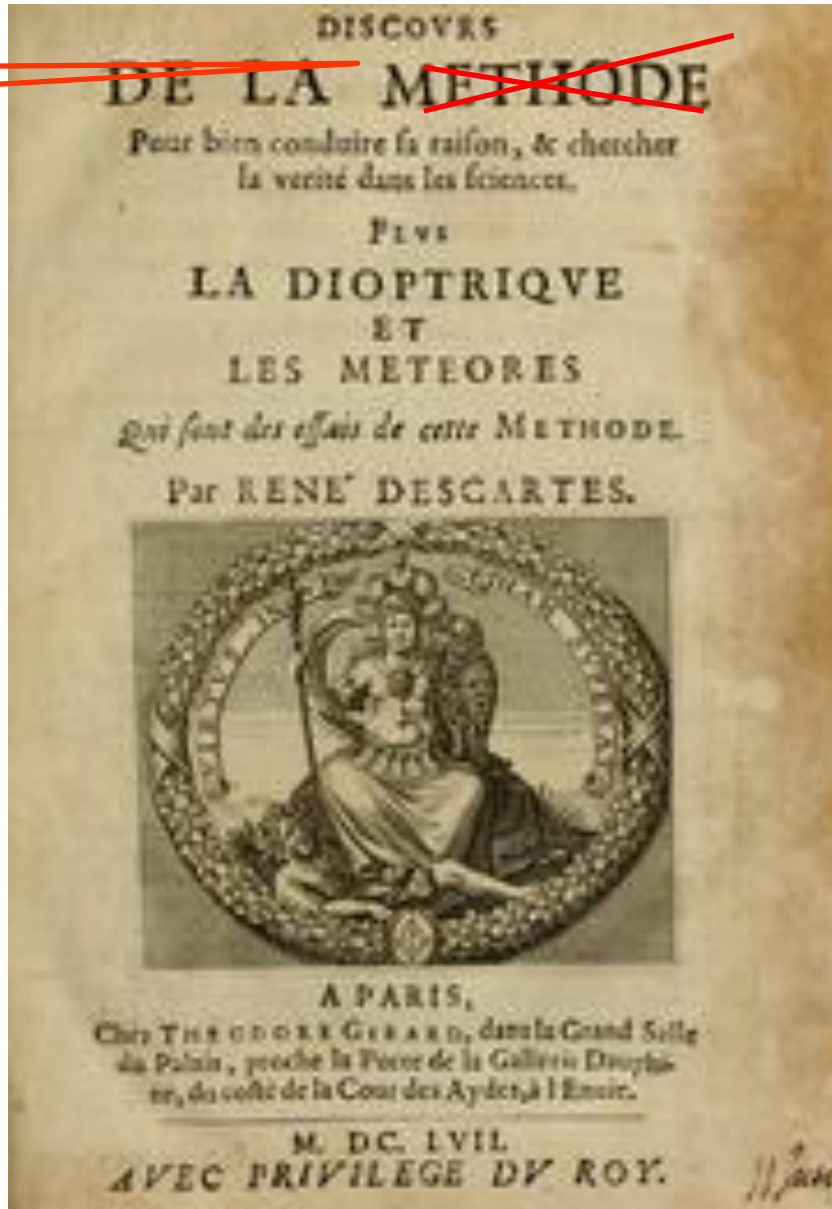


Methodology, method, data and software

- So, primordial to everything is “methodological principles”
- This is not the same as “method”
  - methodological principles lead to a method
- Example:
  - $\mathbf{g} = \mathbf{B}\mathbf{A}^{-1}\mathbf{f}$ is a “method”
  - linear attribution is a “methodological principle”

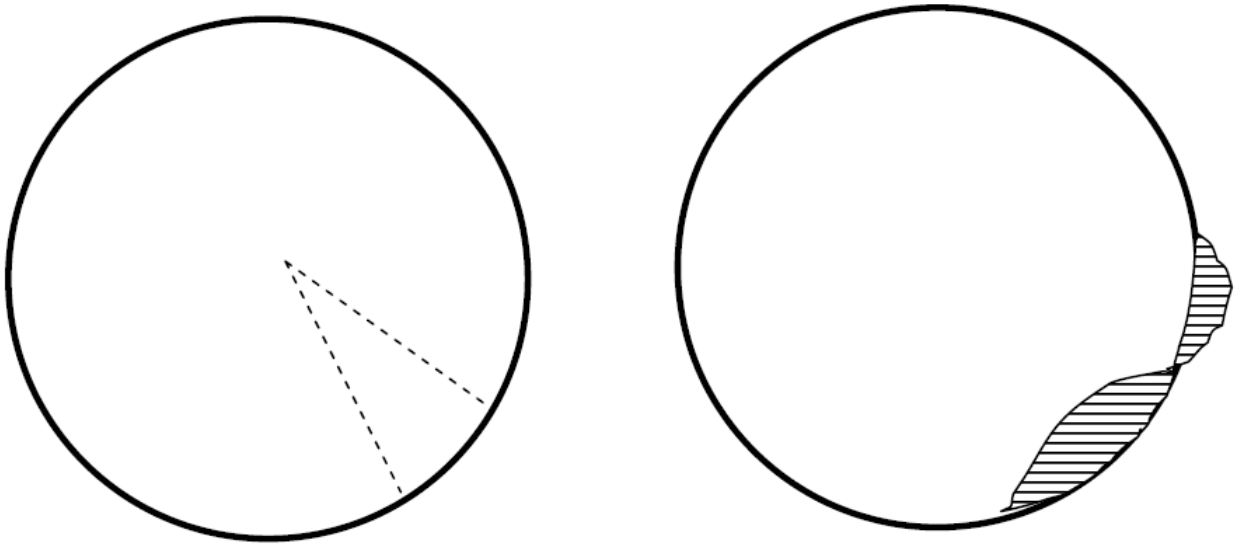
Methodology, method, data and software

METHODOLOGIE


DISCOVRS
DE LA METHODE
Pour bien conduire sa raison, & chercher
la verité dans les sciences.
PLVS
LA DIOPTRIQVE
ET
LES METEORES
Qui sont des essais de cette METHODE.
Par RENE' DESCARTES.
A PARIS,
Chez THEODORE GIRARD, dans la Grand Salle
du Palais, proche la Porte de la Galerie Dauphi-
ne, du costé de la Cour des Aydes, à l'Ecuir.
M. DC. LVII.
AVEC PRIVILEGE DV ROY.

The impact function

- An often-cited illustration of the difference between ALCA and CLCA



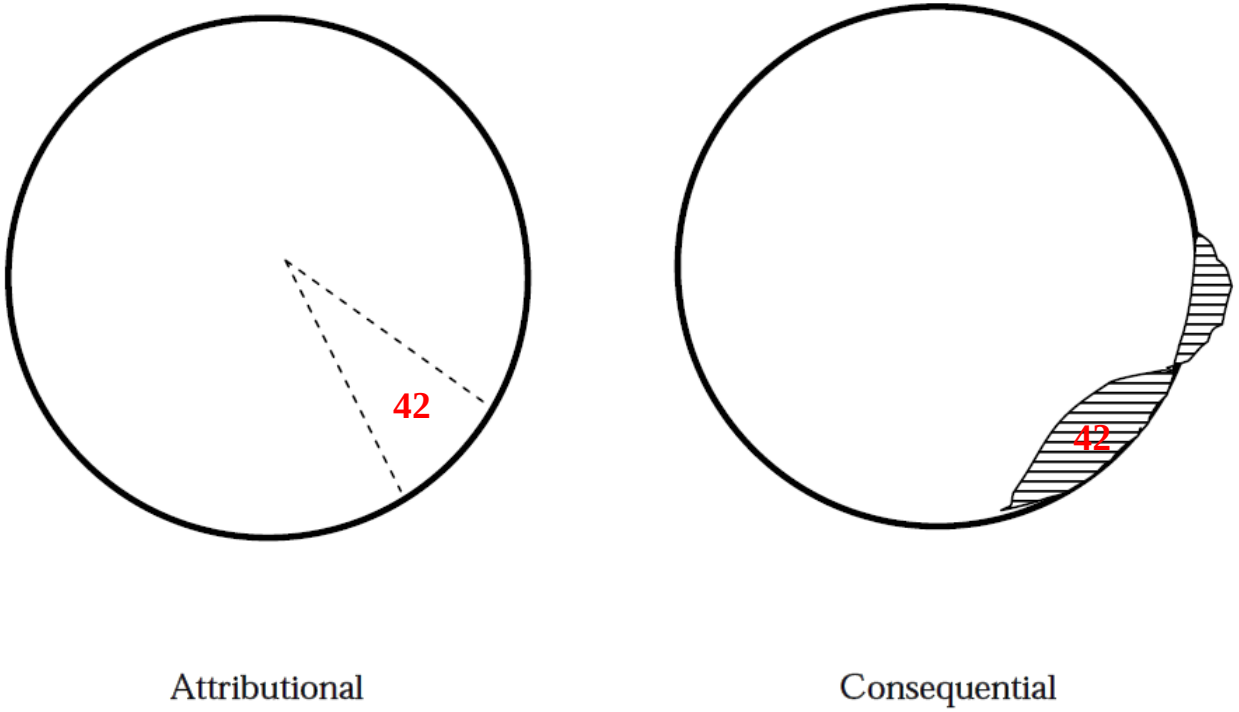
Attributional

Consequential

Weidema, Danish Environmental Protection Agency (2003)

The impact function

- But this is an answer
  - what is the question?



Weidema, Danish Environmental Protection Agency (2003)

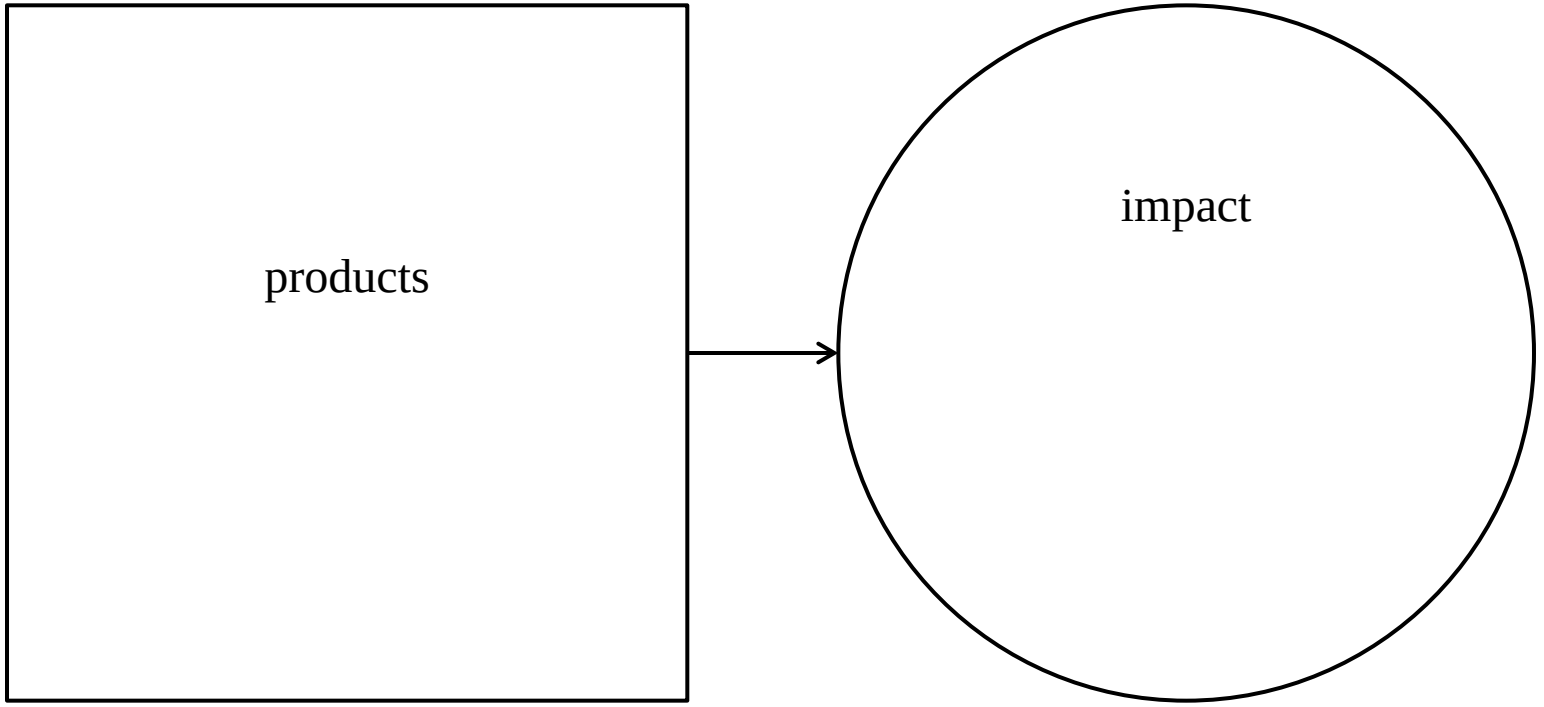
The impact function

- Suppose we know an “impact function” (γ)
  - it maps a bundle of products (f) onto an impact (g)
- Mathematically:
  - $g = \gamma(f)$
  - $\gamma: f \rightarrow g$
- Here:
  - impact = γ(products)
  - γ: products → impact

$$y = f(x)$$
$$f: x \rightarrow y$$

The impact function

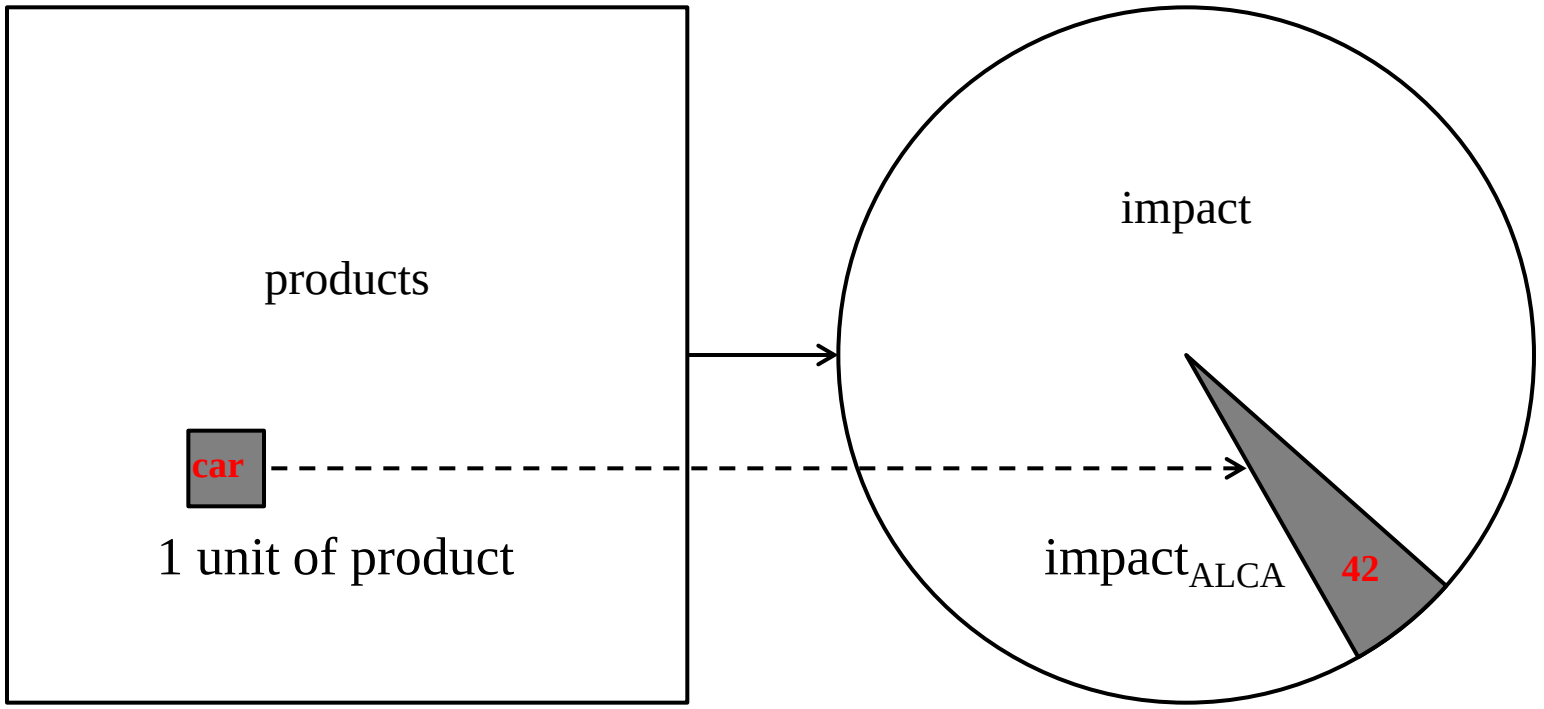
- Whole system



$$\text{impact} = \gamma(\text{products})$$
$$\gamma: \text{products} \rightarrow \text{impact}$$

The impact function

- ALCA

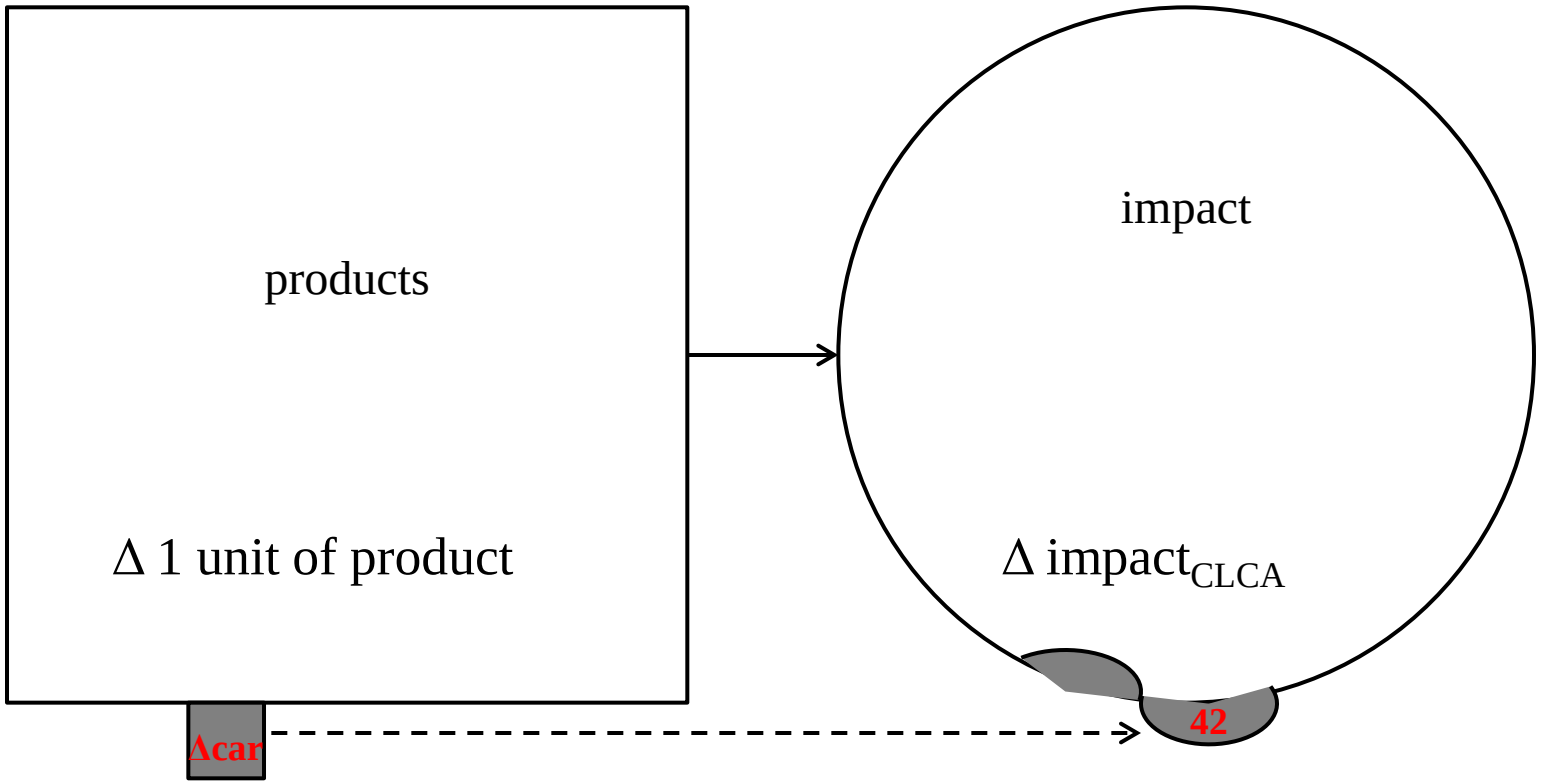


$\text{impact}_{ALCA} = \gamma_{ALCA}(1 \text{ unit of product})$

γ_{ALCA}: 1 unit of product $\rightarrow$ impact_{ALCA}

The impact function

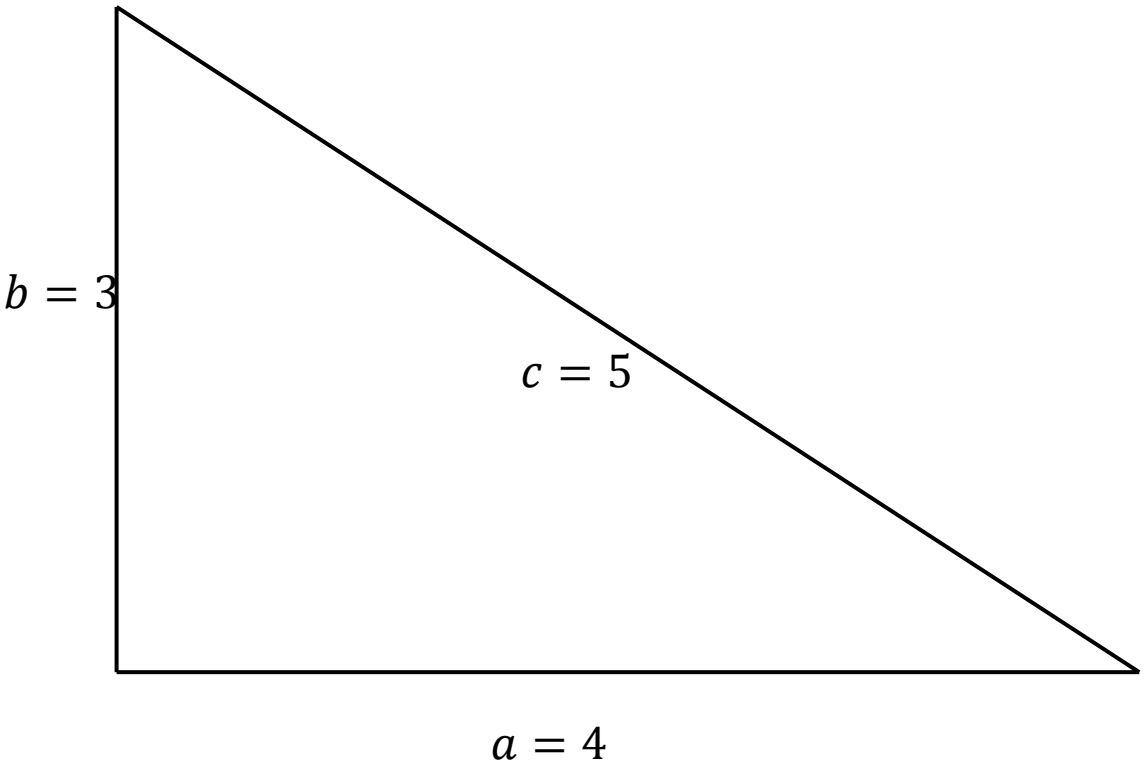
- CLCA



$\Delta\ \text{impact}_{CLCA} = \gamma_{CLCA}(\Delta\ 1\ \text{unit of product})$

γ_{CLCA}: Δ 1 unit of product $\rightarrow$ $\Delta\ \text{impact}_{CLCA}$

LCA as a triangle

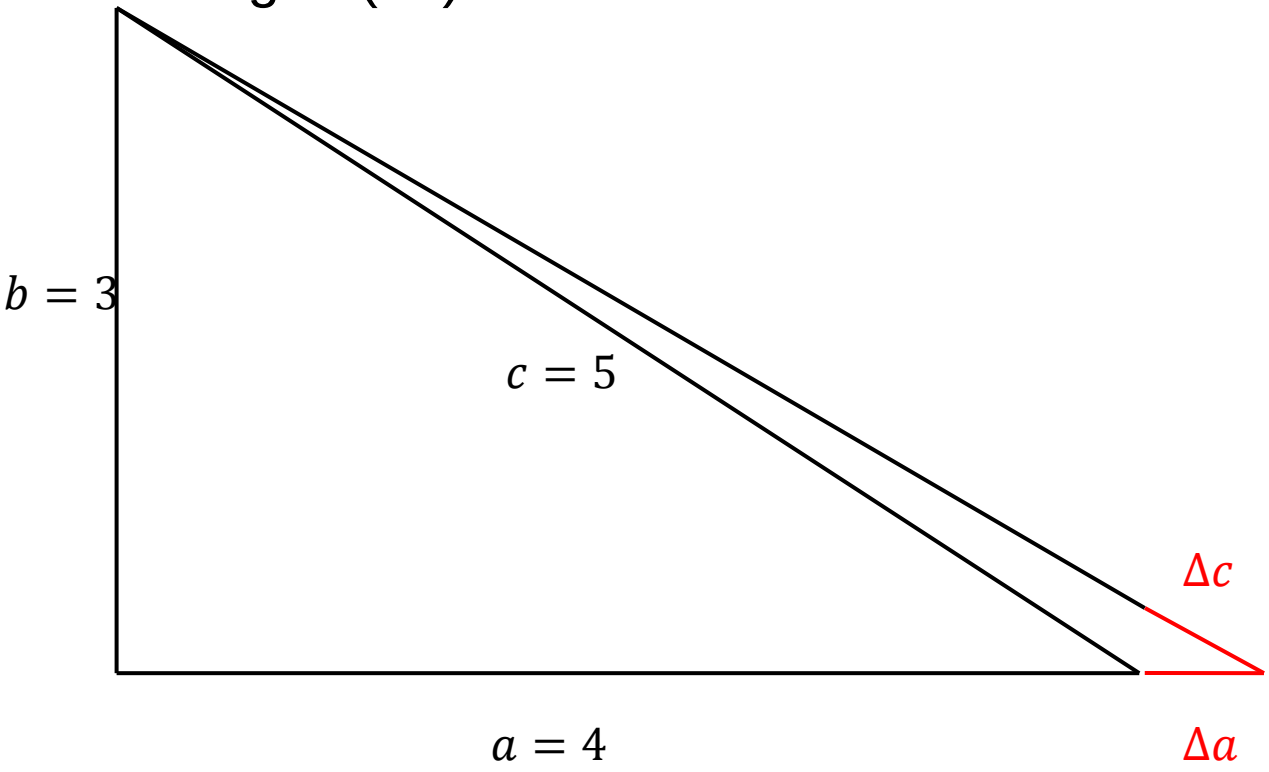


LCA as a triangle

- The “impact” (c) depends on the “products” (a and b)
- Remember Pythagoras?
  - $c = \sqrt{a^2 + b^2}$
  - $\gamma(a, b) = \sqrt{a^2 + b^2}$
- Let’s try to use this “impact function” (γ) to derive
  - “CLCA”
  - “ALCA”

LCA as a triangle

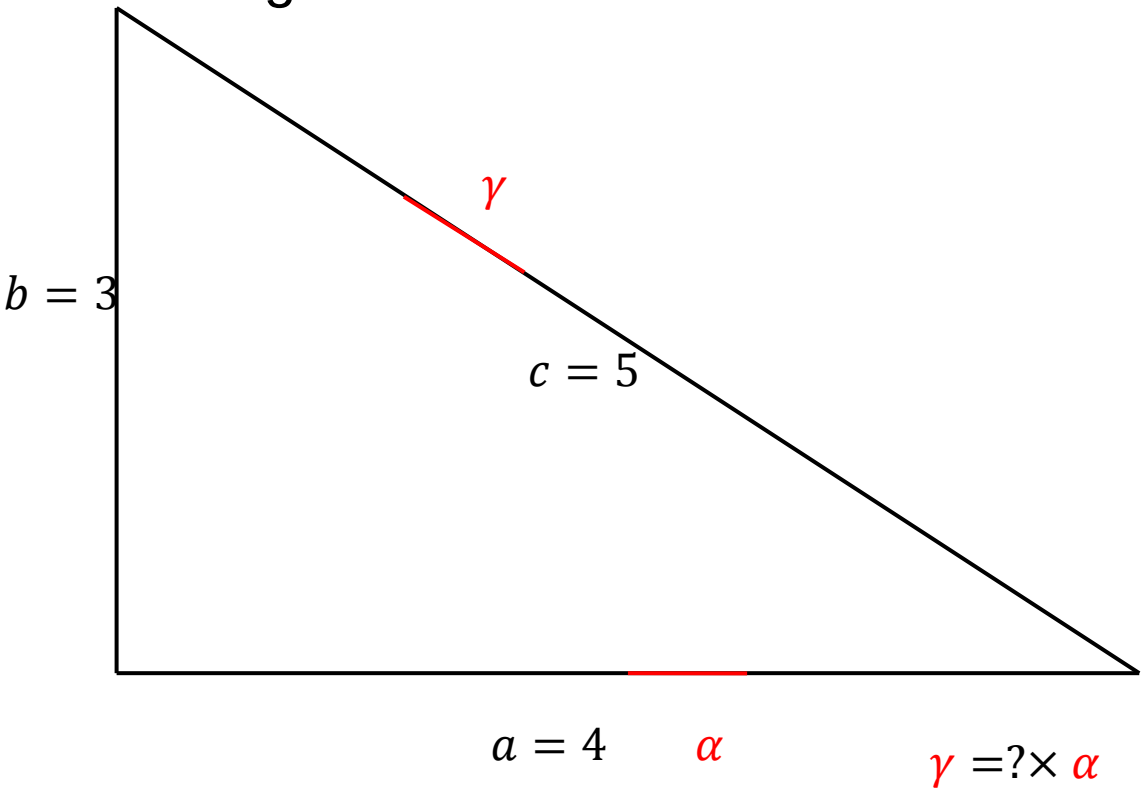
- "CLCA"
- Change a by a certain amount (Δa), and see how c changes (Δc)



$$\Delta c = \sqrt{a^2 + 2a(\Delta a) + (\Delta a)^2 + b^2} - \sqrt{a^2 + b^2}$$

LCA as a triangle

- "ALCA"
- Select a part of a (α), and find out which part of c (γ) belongs to it



Axiomatic ALCA

- How to find the question mark?
- No causality, because no change
- We rely on
  - intuitively nice properties
    - LCA of cup-and-saucer=LCA of cup + LCA of saucer
  - consistency requirements
    - LCA of whole world gives all impacts
- An axiomatic set-up is needed

Axiomatic ALCA

DEFINITION 1
Life cycle assessment is a process to evaluate the environmental burdens associated with deriving utility from a product, whereby the entire life cycle of the product is included. ■

Two axioms stating basic principles will be given first. Obviously, in a more strict approach, many other notions should be defined. Among these are: product, environment, burden and life cycle.

AXIOM 1
Deriving less utility with the same product should give an environmentally preferable result. ■

This is a basic assumption of LCA: a procedure which does not for 5 minutes is for environmental reasons better than doing s constructed. It cannot be proven, however, and is therefore an

AXIOM 2
Producing less environmental burdens for deriving the s environmentally preferable result.

This too is obviously a basic assumption: taking a 5-minute sh heating system is better than taking a 5-minute shower with an

DEFINITION 2
The mathematical function which maps an amount of utility derived from a product to a quantitative assessment is defined as:

$$\mathbf{LCA}: \alpha_x \rightarrow \mathbf{LCA}(\alpha_x)\ [\mathbf{LCA} = \mathbf{LCA}(\alpha_x)]1$$

where α_x represents the fulfilment of a specified utility α by a certain product x, and **LCA** represents the vector-valued function. ■

By defining the LCA-function as a vector in Definition 2, it is left open whether the LCA-function produces one number or a set of numbers. Both possibilities are reasonable and in fact occur in practice. The inventory table and the environmental profile, results of inventory analysis and characterization respectively, are examples of LCA-functions with a multi-dimensional result. An environmental index is a one-dimensional LCA-function.

THEOREM 2
The function $\mathbf{LCA}(\alpha_x)$ is a monotonous function of α_x, the amount of utility derived. ■

PROOF OF THEOREM 2
If $\mathbf{LCA}(\alpha_x)$ would be non-monotonous, there would be an α_x and an $\alpha'_{x'}$ such that $\alpha_x < \alpha'_{x'}$ and nevertheless $\mathbf{LCA}(\alpha_x) > \mathbf{LCA}(\alpha'_{x'})$. This clearly violates Axiom 1. ■

The continuity of $\mathbf{LCA}(\alpha_x)$ cannot be proven at this stage, neither can its linearity. For this, a further axiom is required.

Klostermann & Tukker, Springer (1998)

Conclusion

- What changes in LCA practice is not obvious:
  - not just plugging in marginal data in existing formulas
  - not just using marginal characterisation factors
- But really going back to the drawing room
  - 1: get rid of ISO-LCA (not founded, unclear wrt ALCA and CLCA)
  - 2: develop a “scientific” method for CLCA
  - 3: develop an “axiomatic” method for ALCA
- We’ll see where they agree and where they differ

Conclusion

- Danke schön
- Merci beaucoup
- Grazie

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