

CONSEQUENTIAL MODELLING

- IN LIFE CYCLE INVENTORY ANALYSIS

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LATEST UPDATED APRIL 2022

Overview of videos

- 1) Attributional and consequential responsibility
- 2) ISO 14040/44: A standard for consequential LCA
- 3) How to fully reflect both physical and monetary causalities in LCA
- 4) Temporal issues in LCA
- 5) Learning from non-intuitive results
- ➔ 6) *The comparability algorithm*: Defining the functional unit
- 7) *The linking algorithm*: Composing a consumption mix
- 8) Identifying determining products
- 9) *The co-product algorithm*
- 10) Errors in background databases

The comparability algorithm: What do the standards say?

Unfortunately very little practical guidance

- *Functional unit*: quantified performance of a product system for use as a reference unit (ISO 14040:2006)
- “Comparisons between systems shall be made on the basis of the same function(s), quantified by the same functional unit(s)” (ISO 14044:2006)
- “the scope of the study shall be defined in such a way that the systems can be compared” (ISO 14044:2006)

Turning instead to other sources that have dealt with comparability

- Marketing science
- Competition law

Core literature for LCA:

- Weidema B P (2017). *Short procedural guideline to identify the functional unit for a product environmental footprint and to delimit the scope of product categories*. 2.-0 LCA consultants, report to the Nordic Council of Ministers. <http://lca-net.com/p/2527>

Based on:

- Weidema B P, Wenzel H, Petersen C, Hansen K (2004). *The product, functional unit and reference flows in LCA*. København: Miljøstyrelsen. (Environmental News 70) <https://lca-net.com/p/1050>

Relevant legal definitions

The European Commission (1997):

- A relevant **product market** comprises “all those products and/or services which are regarded as **interchangeable or substitutable** by the **consumer**, by reason of the **products' characteristics**, their prices and their intended use”
- A relevant **geographic market** comprises “**the area** in which the undertakings concerned are involved in the supply and demand of products or services, **in which the conditions of competition are sufficiently homogeneous** and which can be distinguished from neighbouring areas because the conditions of competition are appreciably different in those areas”

Step 1: Market segmentation

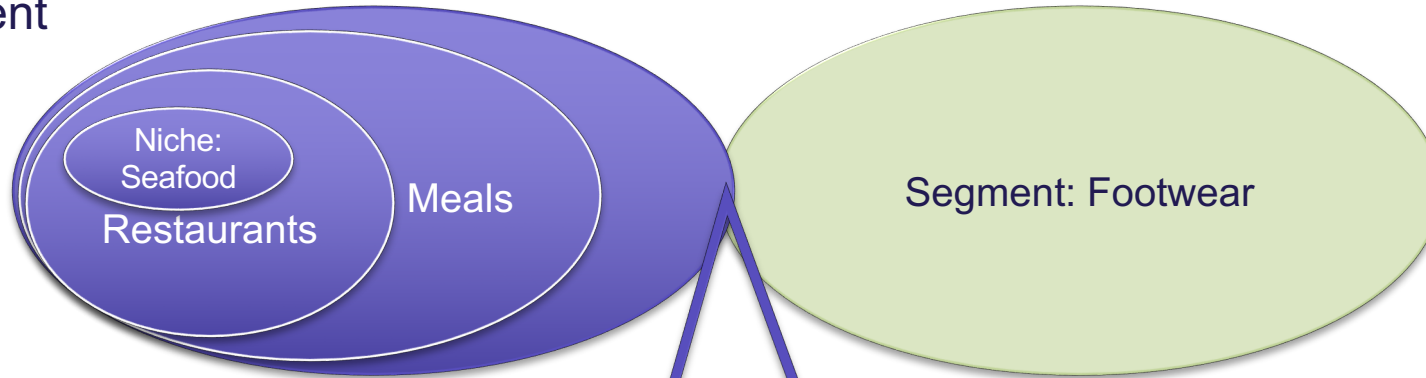
- The **market** is where the customers express their requirements via purchases
 - from which we can identify the **obligatory product properties**
 - that we use to define the **functional unit**
- Three types of segmentation:
 - Geographical segmentation
 - Based on differences in natural geography, regulation (of competition, market entry, legislative product requirements, of public procurement, product standards, packaging regulations, quotas, taxes, subsidies), and consumer culture
 - Documentation/justification: Lack of imports. Except in situations of recently removed regulative barriers or chain substitution ($A \rightarrow B \rightarrow C$).
 - Temporal segmentation
 - Relevant for service products, e.g., electricity and telecommunication, perishable products, and immature or unstable markets, e.g., for some recycled materials
 - Customer segmentation

Customer segmentation

- *Customer segments* are defined as being:
 - large enough to support a separate product line
 - clearly distinct and non-overlapping, so that substitution between segments can be neglected, and all products within each segment are substitutable
- The *same product* may serve different needs (= have different functional units), thus being sold on more than one market, and belonging to *more than one product category*
- Also: *Very different products* may serve the same need (= have the same functional unit), thus being in competition in the same market

A hierarchy of markets: Segments and niches

- Market segments can be divided into **market niches**: Niche customers consider only niche products substitutable, but the majority of customers allow substitution between the niche products and other products in the segment



Data sources for market segmentation

Primarily:

- Marketing departments of the enterprises supplying products to the market

Secondary sources:

- Retailers that cover more than one segment
- Industrial associations
- Industrial research institutions and industrial consultants
- Marketing and consumer research institutions

No segmentation in situations where supply substitution is possible

- **Supply substitution:** When suppliers are able to switch production between various qualities of products in the short term without incurring significant additional costs or risks
 - *Even when* the different qualities are not regarded as substitutable by a given group of customers, customer segmentation is unnecessary
 - The different qualities should anyway be grouped into *one* product market and category
- **Example:** Meat producers may easily shift between different cuts of meat in response to changes in supply and demand
 - These different cuts can be regarded as belonging to the same market and product category, even though the consumers may not regard the different cuts as substitutable
- The same reasoning may be used to avoid unnecessary geographical market segmentation

Example: Food

- All foods are ultimately substitutable, justifying that “Food” can be regarded as a generic product category, which can then be further specified according to the different market conditions
- Consumption takes the form of *meals* and *snacks*, each of which can be regarded as separate niche markets and product categories
- The market for meals can be subdivided into *temporal meal types* (breakfast, lunch, dinner), illustrated by meals suppliers typically changing their menus depending on the time of day
- Substitution *does* occur between temporal meal types and between meals and snacks → justifies that all belong to the same product category
- Besides the temporal division, the market for meals can be subdivided in three, based on the location and type of meal supplier (see next slide). This subdivision is supported by cross-elasticity studies (e.g. ↓)

Okrent et al. 2012: The Demand for Disaggregated Food-Away-From-Home and Food-at-Home Products in the United States. USDA Economic Research Service Report 139).

Example: Three markets for meals

	Home cooked meal	Restaurant meal	Institutional meal
Meal supplier	Household kitchen	Restaurant kitchen	Institution kitchen
Diet planning by meal supplier	Optional	No	Yes (typically)
Alternative meal suppliers	No	Household choice	No
Decision on meal type and courses	Meal supplier (possibly with <i>some</i> household influence)	Household or customer choice	Meal supplier (possibly with <i>limited</i> customer choice)
Decision on course composition	Meal supplier (possibly with <i>some</i> household and customer influence)	Meal supplier (possibly with <i>limited</i> customer choice)	Meal supplier
Decision on portion size	Meal supplier or <i>customer</i>	Meal supplier (except for buffet service)	Meal supplier (except for buffet service)
Decision on ingredients	Meal supplier (possibly with <i>some</i> household and customer influence)	Meal supplier (possibly with <i>limited</i> customer choice)	Meal supplier (possibly with <i>limited</i> customer choice)

The three markets differ in the freedom they give for further customer influence on further segmentation

The markets for meals are delimited to the points where it is the **meal customer** that takes the decision, while for the other markets, it is the **meal provider** that is the customer (decision maker)

Further niche markets for meals

- **Home cooked meals and institutional meals:** *No need* for further market segmentation due to the large influence of the meal supplier on the decisions
- **Restaurant meals:** The larger customer influence on choice of supplier (alternative restaurants), meal type, and courses makes it reasonable to identify *further customer segments:*
 - **Data sources for restaurant customer segmentation:** Categories used by Internet search portals, such as Tripadvisor®:
 - Price level
 - Cuisine, typically divided by region, nationality or typical ingredients (e.g., seafood), dishes (e.g., pizza, steakhouse), preparation methods (e.g., barbeque, sushi) or presentation methods (e.g., buffet), and
 - Dietary restrictions (vegetarian, halal, etc.)
- Suppliers will typically *not* be able to switch easily between these segments

Step 2: Identify the obligatory product properties

- Out of all the properties that a product may have, *all* the obligatory properties, and *only* those, shall be included in the functional unit
- Obligatory product properties are those that the product *must have* in order to be at all considered as a relevant alternative, and are typically related to:
 - Functionality, associated with the main function of the product
 - Technical quality, such as stability, durability, ease of maintenance/repair,
 - Additional services rendered during use, recycling or disposal,
 - Costs related to purchase, use, recycling or disposal,which can all be described in *quantitative* terms, *typically as intervals* with minimum and/or maximum values
- Thus, a quantitative description can be given, covering at least the functionality (*what*), the expected level of quality (*how well*) and the duration/lifetime of the product (*how long*)
- The same product property may be obligatory in one market and not obligatory in another market

Data sources for obligatory properties

For a specific market segment, information can be obtained from:

- The marketing departments of the enterprises supplying products to the market segment
- Retailers
- Industrial organisations
- Industrial research institutions and industry consultants
- Regulating authorities and standardisation bodies
- Marketing and consumer research institutions

Information on obligatory properties

The information will often be of three kinds (in order of preference):

- Issues regulated in national and international legislation and standards
- Evidence from market events or shocks in the recent past
- Information from market surveys
 - Market surveys are especially useful if they ask for what competing products the customers have considered, and/or what properties/attributes are regarded as obligatory/mandatory for a purchase
 - More advanced surveys may use choice experiments, where consumers are asked for their preference for goods with different levels of different properties/attributes, often with price (willingness-to-pay) as one of the properties

Quantitative techniques

- A number of quantitative analytical measures have specifically been designed for the purpose of identifying substitutability:
 - Cross-price-elasticities ($\Delta\%$ in demand for one product per $\Delta\%$ in the price of another product)
 - Similarity or convergence of price movements over time
 - Causal relations in price series
- Normally only required if the existence or lack of substitutability is subject of a controversy
- It is **not** necessary to have access to the resulting *numerical* information of willingness to pay, cross-elasticities, or diversion rates
- All that is needed is the information that a specific property or product has a positive cross-elasticity, i.e., that an increase in price of one product or property leads to an increase in sales of the other product with a different property → From this it can be concluded that the two products and properties are regarded as substitutable, at least for a part of the customers

Food example:

“how much?” and “how long?”

- The **portion size** provides the “how much” is consumed in a meal, but will also determine “how long” the customer will feel satiated, i.e., how much time will pass before an additional meal or snack will be demanded
- **Satiety** can be determined by:
 - Subjective scores
 - The compensation score, i.e., the relative reduction in energy intake at later meals expressed as a percentage of the energy of the preload meal
 - Serum levels of ghrelin (“the hunger hormone”), which is closely inversely correlated to satiety

“How long?” could also be related to time used for preparation and/or consumption

- Especially in the “fast food” market niche, preparation and consumption time could be relevant as an obligatory property
- This may be related back to the market delimitation of “fast food” as a market niche
- This example shows identification of obligatory product properties and market delimitation may be iterative steps in the procedure

Food example: “how well?”

- *Absence of contamination*, i.e., that the consumption of the food does not imply a health hazard, and *absence of adulteration*, i.e., that the food or its components have not been intentionally substituted or diluted for the purpose of reducing production costs or increasing the apparent value of the product
 - Typically regulated by law and enforced by sample testing and inspections of Good Manufacturing Practice (GMP) by national regulatory agencies
- *Codex Alimentarius requirements* can generally be seen as obligatory
 - The Codex is a collection of international standards on foods, covering both general practice guidelines (e.g., for manufacturing, measurements, and labelling), and standards for many specific foods (canned salmon, preserved tomatoes, etc.)

Food example: More obligatory properties

- Some properties may be determined as obligatory either for the meal or snack as such or as an average over several meals and snacks, i.e., as a diet requirement:
 - Price range or budget range
 - Maximum time allowed for preparation and consumption
 - Health concerns formulated as general rules of exclusion, maximum or minimum inclusion, and in the case of formal meal planning in institutional kitchens as specific nutritional requirements
 - Variation: A minimum time since the same meal, meal component, or snack was served (not applicable to restaurants)
- Some properties may be obligatory for specific dishes or components:
 - Shelf-life
 - Serving temperature range
 - Ranges of flavours, flavour strength, and texture properties, with several measurement methods specific to different foods, mainly applicable to food ingredients with standardised brands
- Niche markets may furthermore specify obligatory requirements for:
 - Cultural and ethnic food preferences
 - Special dietary needs
 - Special occasions

Examples of the use of cross-elasticities

- **Positive** cross-price elasticity between **beef and pork** → These meats are **substitutes** and therefore have a common market → They should be placed in the **same product category**
(which still allows to define additional niche-markets where customers in specific segments will regard beef and pork as separate non-comparable products)
- **Negative** cross-price elasticity for coffee with respect to milk → milk is a **complement** to coffee → Although belonging to different **non-substitutable** product groups, milk should be included as a complementary product in an LCA of coffee and coffee substitutes

Step 3: Quantify the functional unit

- This last step is limited to define the functional unit in terms of a **quantity** (“*How much*”) of the product
 - as defined by its **obligatory product properties** required in the market segment (which were *already identified* in the previous steps)
- The functional unit should as far as possible relate to the **functions** of the product rather than to the physical product
 - For example, rather “Seating support for minimum 7 years” than “1 office chair”
- In this way, it is ensured that all obligatory properties (“*How well*”) – as well as the duration of the product performance (“*How long*”) – are addressed

Food example:

Functional unit for an institutional meal

- “Dinner meal with a satiety-weighted energy content of 1500 kJ,
 - with protein quality not less than 80% of the DIAAS adult reference value,
 - with no less than 3% of the energy in the form of linoleic acid,
 - with a purchase price range between 4 and 6 EUR for the sum of meal ingredients,
 - including minimum two fresh vegetable ingredients with a total minimum weight of 225 gram of which maximum 50% can be juice,
 - with all measurements, ingredients and preparation procedures fulfilling all relevant Codex Alimentarius requirements,
 - and fulfilling all further requirements specified for the product categories of each specific meal component and ingredient.”

Does the size of the functional unit matter?

- For LCAs that support small decisions:
 - Consequences can be assumed to be linearly related to the size of the decision, so the size of the functional unit does not matter
 - However, for ease of comparison, it may be an advantage to set the size equal or close to the annual per person consumption of the studied product in the studied market segment
- For LCAs that support specific decisions with large (non-linear) consequences:
 - The functional unit should have the same size as the expected outcome of the decision

Summary of the procedure

Comparability is only possible when:

- The functional *unit* reflects the *substitutability* of the product in its *market*, where the product has a functional specification that the customer requires to be fulfilled: the *obligatory product properties*

Thus, the procedure has three steps:

- Step 1: Identify the *market segment* for the product
- Step 2: Identify the *obligatory product properties* in this market,
- Step 3: Express the functional unit as a *quantity* of the product as defined by the obligatory product properties

Now:
Time to digest !

