The problem of allocation: some more complications

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Abstract in five thesises

a) Allocation is everywhere.
b) Allocation is the core of LCA.
c) Causality is not the answer but the question.
d) There is a strong relation between the definition of LCA, the choice of the functional unit and the system boundaries, and the remaining allocation problems.
e) LCA doesn't, can't, and shouldn't cover all environmental considerations.

Allocation as an LCA-definition problem

The economic system is a complex of actors, which exchange materials, products, services and waste, thereby making use of the environment as a source and as a sink. The environmental system is a complex of processes, which interact in a delicately fine-tuned fashion, and on which the impacts, exerted by man's economic activities, act as a disturbing factor, both physically and chemically. So, the complex of economic activities is what I shall call "responsible" (only in the causal and not in the moral sense!) for the complex of environmental problems.

In the environmental sciences, one studies this causal responsibility. One of the key questions here is the following: *Which economic activity is responsible for which environmental problem?* One can rephrase this question as an allocation problem: *Which environmental problems are to be allocated to which economic activity?* (Figure 1)

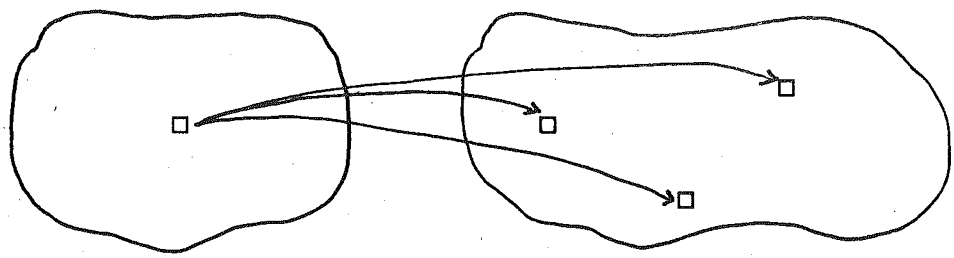

FIGURE 1. The core of every environmental analysis or assessment is which environmental problems to allocate to which environmental activity.

One can answer these questions in various ways, depending on the definition of responsibility:

a) The user of a car is responsible for a certain emission of CO_2 from the combustion of petrol;
b) The user of a light bulb is responsible for the generation of electricity (of course he isn't for the way in which it is generated, but indirectly he is in some sense; being responsible is thus not synonymous to having influence), and thereby for a certain emission of SO_2;

c) The producer of a music cassette is responsible for the fact that a number of people will play it on a walkman, and thus use batteries, with all their impacts;
d) A musician is responsible for his recordings, and thus for the fact that his music is broadcasted, with associated emissions;
d) The reader of a newspaper is responsible for a large supply of secondary paper, and thus for impacts associated with the use of recycled paper;
e) The producer of a newspaper is responsible for the advertisements for cars, and thus for the resulting increase in car use.
f) Who eats hamburgers is responsible for the impacts of how the owner of the snackbar spends the money.

Some of these examples are far-fetched. It is clear that it is improbable that people arrive at a common definition of responsibility. What should be aimed at, however, is a common definition of the realm of responsibility studied in LCA.

Allocation as an extra-functional unit problem

In this paper we will take the life cycle definition. One chooses a certain functional unit, e.g. eating a loaf of bread, and defines the associated life cycle, consisting of agriculture, baking, selling, etc. Usually one excludes things which are only vaguely connected to the life cycle, such as lighting a candle during the course, or using toothpaste after it. The guiding principle here is that of causality: what happens because of the life cycle is part of the life cycle. But this is still too vague and yields choices which cannot be fully agreed on. Another solution is provided by restricting to the analysis of differences. In order to compare two different types of bread, one leaves out the candle, as the analysis assumes the lighting to be identical. It is very difficult to judge to what extent this is true. Can one compare going to the opera and attending a rock concert, leaving out the clothes? The problem of what to allocate to what illustrates that choosing the functional unit and choosing the system boundaries are strongly related.

Allocation as an intra-functional unit problem

So far, the question of allocation is one of functional units and system boundaries. The question whether impacts of lighting a candle is to be allocated to eating bread is usually solved by drawing a boundary between which processes are considered to be part of the life cycle and which are not. Some of these boundaries however run through a process, instead of between two processes. A classic example is the coproduction of sodium, chlorine and hydrogen in one combined process. Which of the process's impacts are to be allocated to a life cycle containing chlorine production?

Traditionally, three main categories of allocation problem are discerned:
a) Coproduction, as in the above mentioned case of the production chlorine, sodium and hydrogen;
b) Combined waste handling, for example the incineration of a plastic bottle and a diaper;
c) Open-loop recycling, in which waste is transformed into a usable product or material.

This division is based on a combination of economic criteria and the direction of the flow of material commodities: allocation problems occur if there are two or more outputs with proceeds, two or more inputs with proceeds, or one or more input and one or more output with proceeds.

Things can be made more complex, however, by introducing processes without proceeds, or with virtual proceeds. A refrigerator represents an interesting example. Cooling food in a refrigerator causes impacts, and if one is to calculate the impacts of the life cycle of beer, one has to decide on the allocation of the impacts of cooling. Clearly, the refrigerator operates for all food inside, but without providing proceeds. So, is this coproduction, combined waste handling or open-loop recycling? Most people hold that it is coproduction, as at is a collection of independent functions (namely cooling) that is the offspring of the process. But this argument is void, as handling waste is also a service.

Next consider the life cycle of a book. Most people read a novel once, and put it in their bookshelf for the next years. Maybe a friend borrows the book a few weeks, or maybe the owner re-reads it once. After thirty years the book is sold to an antiquary, or given to the Red Cross, who puts it in a hospital where it is read a number of times. Many years thereafter, the book's paper is recycled into corrugated board. If the owner reads it twice, there is coproduction without proceeds. If he sells it to the antiquary, there is coproduction with one times proceeds. Maybe, the book turns out to be a rare first edition, so that the antiquary offers much more than it originally costed. The allocation problems of a book seem complicated.

Ways to handle allocation

For coproduction, physical parameters, such as the mass ratio between the various outputs are often used as a basis for allocation. Sometimes economic parameters are used, as they reflect in some cases the causality better then physical parameters. For combined waste handling, attempts to model the physico-chemical causality are currently being made. For open-loop recycling, there is a dichotomy between approaches which take the entire material cascade into account and approaches which concentrate on the two applications connected by the recycling process.

Indeed, causality may seem an appealing principle for allocation. But it is a sort of turning things around. The whole exercise of LCA is undertaken as an interpretation of a question: *Which economic activity is responsible for which environmental problem?* And the guiding principle here was taken to be causality. So, causality is the main principle, and the theory of LCA has to tell how to assign concrete procedures and numbers to this principle. A number of examples of causal relationships will be given below.

a) Logical requirements: a product must be produced before it can be used;
b) Legal requirements: a used products must be treated according to some standards;
c) Economic requirements: an aircraft carries passengers and cargo, the ratio of the amounts is determined by economic considerations;
d) Environmental requirements: some products are recycled into secondary ones for reasons of environmental benefit.

There is a hierarchy in these causalities. Suppose that a certain product produces a certain waste stream. Laws cannot forbid this, but can instead require that the waste be treated appropriately. Within the logical and legal constraints, the cheapest solution can be found, or the greenest, or an intermediate not-too-expensive-but-still-green one. For example, the cheapest solution is landfilling, the greenest reuse, and the compromise incineration with recovery of energy. It is hard to say how to allocate the emissions of the incinerator to the product, as the causality is of a quadruple nature.

An example of the historic-environmental causality follows. To prevent emissions of dioxins, new incinerators operate at a higher temperature. This higher temperature has side-effects: the ratio between Cr^{3+} and the much more toxic Cr^{6+} becomes more dangerous. One could argue that the increased toxicity due to chromium must (partly) be allocated to chlorine containing products. The moment we allow for this, we introduce a very complex type of historic reasoning, which suggests us that we should restrict the concept of causality to history-independent, natural relationships. But it is difficult to explain to the chromium producing industry that their products have become worse. They can't help.

Allocation is everywhere

In many studies, the problem of allocation receives little or no attention. People often think that it is a minor issue or doesn't occur at all in their case study. My thesis is however that it occurs everywhere, in fact in every process.

First of all as a LCA-definition problem. One could ask what is the greenest way to spend money. A preliminary answer would be to give it away. But do not forget the secondary effect: give it to someone who doesn't buy polluting products, but to someone who gives it away to someone who gives it away to ... This silly type of reasoning is the extreme consequence of not allocating in the sense of restricting LCA.

Secondly, we have extra-functional unit allocation problems. Take the example of the life cycle of a radio. When we include the impacts of the broadcasting station, there is an allocation problem, namely how to allocate these impacts to listening one hour to one radio? When it is excluded, this problem has been solved, just by omitting it. In contrast, things can also be come more complicated by narrowing system boundaries. If we study packagings for milk, we have to decide on the allocation of transport among milk and packaging. If we study the combined system, on the other hand, this allocation problem has disappeared.

Lastly, there is the intra-functional unit boundary. A tacit assumption underlying many studies is the allocation of ordinary processes. When producing 10.000 tons of steel requires 50.000 tons of iron ore, it is assumed that 1 kg of steel requires 5 kg of iron ore. The inventory table is calculated as a linear combination of processes. This means an implicit choice for allocation of every process. The difference between short-term versus long-term marginal process data occurs here. Less obvious examples are the allocation of the impacts of constructing highways to one car-kilometre, or of the transportation of one can of beer along with other aliments in a consumer's car, or of the cooling of beer along with other aliments in a refrigerator, and of course the three archetypes of coproduction, combined waste handling and open-loop recycling.

Allocation is really everywhere; it is in fact the core of LCA. It is even the core of every environmental assessment, as one asks *Which environmental problems are to be allocated to which economic activity?* A clear separation between problems related to the definition of LCA, the extra-functional unit allocation and the intra-functional unit allocation is required. This includes the question to which category open-loop recycling belongs. I think LCA could be defined as one class of answer to the extra-functional unit boundary question. In other tools for environmental assessment, such as environmental impact assessment and substance flow analysis, other boundaries are defined. (Figure 2) Only the details of the extra-functional unit boundaries and the intra-functional unit boundary question then remain to be solved. Establishing a hierarchy of causalities – logical, legal, economic, environmental, etc. – could help to formulate a better guiding principle than just plain causality.

Towards a hierarchical solution

From the arguments above, a hierarchical approach emerges:

a) The definition of LCA can solve certain allocation problems.

Not everything which is environmentally relevant can or must be part of LCA. The life cycle of money is considered not to be part of LCA. It is possible to prove that EIA-like aspects cannot be included in LCA. Other aspects (e.g. working conditions) might be included, but I strongly doubt whether this makes sense. The same remark applies to material cascades.

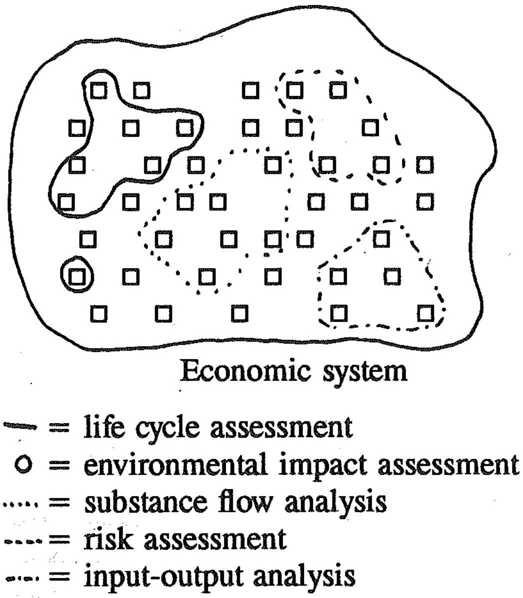

FIGURE 2. The economic system consists of a huge number of unit processes (□). Different groupings of processes correspond to different types of analysis and thus to different instruments.

Maybe a separate tool (recycling analysis?) should be developed, in order to cover some important elements not covered by LCA. If we agree on the exclusion of material cascades from LCA, the related allocation problems are solved by definition.

b) The choice of the functional unit and the system boundaries can solve certain allocation problems.

Here it suffices to refer to the LCA of a radio, with or without broadcasting station, and the life cycle of milk packaging, with or without contents.

c) Only the remaining allocation problems have to be solved.

The allocation of the impacts of a refrigerator to the life cycle of beer provides a complex example. If we allocate on the basis of heat capacity, we neglect part of the impacts. We could allocate these missing impacts on the basis of mass, volume or number of products. But a marginal approach could also be proposed.

I think that separation of the allocation problem in these three questions is an elegant way to deal with the general allocation problem. There is a dichotomy between practitioners and theoreticians. Practitioners tend to be able to solve any allocation in practice. They are able to give guidelines for their particular field of experience. Theoreticians, on the other hand, should try to formulate examples of an ever increasing complexity. Being able to solve the most complicated examples implies possessing the key to a broadly applicable solution.