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## **TOWARD A STRUCTURED FUNCTIONAL UNIT DEFINITION FRAMEWORK TO LIMIT LCA RESULTS VARIABILITY**

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### **ABSTRACT**

Functional Unit (FU) ensures the consideration of comparable product quantities to provide reliable Life Cycle Assessment (LCA) results. Although the definition of this FU is essential, it receives only a few attention in the normative texts. A high part of subjectivity is let to the LCA practitioner. In this paper variability sources of the FU definition are identified to propose a more structured and adapted approach. Literature references and data collected among 8 LCA experts on 5 case studies allow us to draw first recommendations towards a more structured FU definition framework.

### **INTRODUCTION**

Life Cycle Assessment (LCA) is performed in product design to measure the environmental performance. In order to ensure the consideration of comparable product quantities to provide reliable LCA results, the concept of Functional Unit (FU) has been introduced. It is well known that LCA is extremely dependent on this FU. It needs to be carefully defined in relation with the objectives of the study. However only a few attention is given in the normative texts to the definition of the FU, which lets a high part of subjectivity to the LCA practitioner. No clear rule is given to define the right FU for a particular study. For this reason, the survey of unresolved problems in LCA proposed by Reap et al. (2008) brings to attention the importance of the definition of the FU as it is a frequent cause of uncertainty.

In the ISO 14040:2006 standard, the FU is defined as the “*quantified performance of a product system for use as a reference unit*” (ISO 14040:2006). This standard, as well as ISO 14044:2006 highlights the FU importance to provide reliable LCA results in comparative assessments. ISO 14044:2006 states that the FU should be clearly defined and measurable (ISO 14044:2006), but no guideline is given to structure it. The ILCD Handbook goes a step further by proposing to define the FU by answering four questions: “*What ?*”, “*How much ?*”, “*How well ?*”, and “*For how long ?*” (Joint Research Center - Institute for Environment and Sustainability, 2010). Cooper also proposes to standardise the FU by considering three factors: magnitude of service, duration of service and expected level of quality (Cooper, 2003). No special attention is given to the function itself. Esterman et al. adopt a Functional

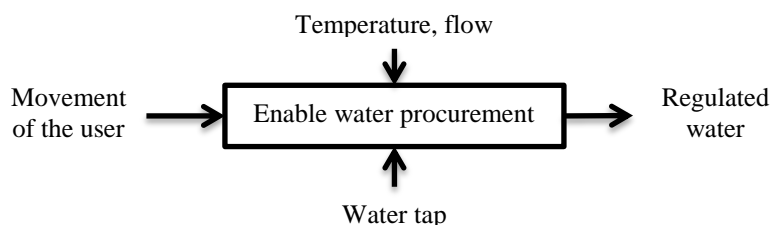
Analysis-based approach to help standardising the FU. They particularly recommend using an active verb-noun pair as the first step to a rigorous FU definition (Esterman, Fumagalli, Thorn, & Babbitt, 2012). Finally, Collado-Ruiz and Ostad-Ahmad-Ghorabi (2010a) introduce the Fuon theory to standardise FUs. *Fuon* stands for Functional Icon and it is defined as “*an abstraction of a product, based on its essential function and representing the whole set of products that share the parameters for this function’s flow*”. By identifying the Fuons associated to a product, it is thus easier to define a valid FU and to compare the environmental performance of products sharing same Fuons. However if this framework seems promising to ensure the consideration of comparable products functions, it does not focus on how to identify FU components and how to express the FU itself. In this paper some of these literature findings are tested thanks to FUs provided by 8 experts on different case studies. Then first directions towards a more standardised approach are introduced.

## METHOD

The objectives of our research are: (1) To identify among the literature propositions of what are the expected variability sources for the FU; (2) To test on case studies if the consideration of such sources allows a better FU standardisation between different users; (3) To test on case studies what are among these expected variability sources the real ones, i.e. the sources that have a real influence on LCA results; (4) And finally to propose a unified framework to define reliable FUs. In the preliminary research presented in this paper, the gap existing between different FUs is illustrated on a case study by considering the expected variability sources issued from the studies presented in the previous section, and to make first propositions toward a more structured approach. We have asked 8 French LCA experts to define a FU for 5 case studies: a coffee maker, a smartphone, a camera, an electrical motor, and a water tap. Results concerning the water tap are presented in this paper. Five parameters are supervised: *presence of an infinitive verb*, and the four ILCD parameters (*What?*, *How much?*, *How well?*, and *For how long?*).

## RESULTS

Figure 1. Simple SADT representation of the water tap



The case study is a mixer water tap for domestic use. A simple SADT is presented in Figure 1 to illustrate the product. 8 FUs were collected from the experts. Examples of answers are “*Allow the flow of cold and hot water to clean the dishes and any other cleaning activity (in litres per day)*”, “*Lifecycle of a mixer tap*”, or “*Enable to obtain water at a given temperature*”. They are qualitatively very different. Table 1 shows the presence or the absence of the five supervised FU parameters. If the two first ones (*Verb* and *What?*) are well

represented, it is highly different for the three other parameters. This result shows a high variability of the FU on a same case study for different users.

Table 1. Presence or Absence of the main FU parameters for the 8 water tap FUs

| Parameter | Verb | What? | How much? | How well? | For how long? |
|-----------|------|-------|-----------|-----------|---------------|
| FU1       | Yes  | Yes   | No        | Yes       | No            |
| FU2       | No   | No    | No        | No        | No            |
| FU3       | Yes  | Yes   | Yes       | Yes       | Yes           |
| FU4       | Yes  | Yes   | No        | No        | Yes           |
| FU5       | Yes  | Yes   | Yes       | No        | Yes           |
| FU6       | Yes  | Yes   | Yes       | Yes       | No            |
| FU7       | No   | No    | No        | No        | No            |
| FU8       | Yes  | Yes   | No        | Yes       | No            |

However, it does not show if the FUs sharing the same elements are similar or not. Going a step further, Table 2 proposes a similarity matrix to analyse the distance between the FUs. The scale used for this assessment is adapted from (Collado-Ruiz & Ostad-Ahmad-Ghorabi, 2010b) and linked with Functional Analysis terminology. “I” means *Identical* (same primary and complementary functions even if the quantitative elements are different), “S” means *Similar* (same primary functions), “C” means *Close* (at least one common primary function) and “D” means *Different* (no common primary function). This table shows that even if the same parameters are included in two FUs, they may not be similar.

Table 2. Similarity matrix of the 8 water tap FUs

|      | FU 1 | FU 2 | FU 3 | FU 4 | FU 5 | FU 6 | FU 7 | FU 8 |
|------|------|------|------|------|------|------|------|------|
| FU 1 | I    | D    | S    | D    | C    | S    | D    | C    |
| FU 2 | D    | I    | D    | D    | D    | D    | D    | D    |
| FU 3 | S    | D    | I    | D    | C    | S    | D    | C    |
| FU 4 | C    | D    | D    | I    | D    | D    | D    | D    |
| FU 5 | C    | D    | C    | D    | I    | C    | D    | S    |
| FU 6 | S    | D    | S    | D    | C    | I    | D    | C    |
| FU 7 | D    | D    | D    | D    | D    | D    | I    | D    |
| FU 8 | C    | D    | C    | D    | S    | C    | D    | I    |

Another analysis that may be performed is to study the LCA perimeter variability associated with each of these FUs. Graphical results are not presented in this paper, but the technical elements (heating system, pipes, sink...) or even the user may be easily included or excluded from the study perimeter by considering the FUs. So 5 different perimeters are obtained with the 8 FUs, which may probably conduct to different LCA results.

## DISCUSSION

At this point, first recommendations to standardise FU definition may be formulated. Even if LCA results associated with our case studies are not yet available, it is evident that the lack of

accurate guidelines or formal elements to compose a FU leads to a high variability of FU on a same case study. With 8 FUs sharing some elements or functions, 5 different LCA perimeter potentially associated with contradictory conclusions and decisions are obtained. Starting from the existing literature, our first recommendations are to gain experience from the Functional Analysis field, which permits rigorously defining primary and complementary functions as well as constraints based on a verb-noun structure. We also propose to structure each of these functions around the four elements of the ILCD Handbook : the form of the output (*What?*), the magnitude (*How much?*), the performance (*How well?*) and the duration (*For how long?*). Moreover the results presented in the previous section raise some issues that need to be further analysed in future studies. The first one consists in analysing using appropriate LCA simulations the contribution of each of these formal elements to assess if they are really necessary to define a valid FU or not. The second one is to work on guidelines or methods to limit the variability in the content of each formal element. A complementary study has been started to assess FU variability for the same user according to the level of information and training he has.

## CONCLUSIONS

We have proposed in this paper a synthesis of existing studies concerning Functional Unit definition in LCA. Starting from these literature references, some expected sources of variability have been highlighted and tested on case studies. Results show the importance of structuring the FU with such elements, but also the need to offer clear guidelines concerning the content of these elements themselves. Future work will deal with the realisation of LCAs to precisely determine the contribution of each element to the LCA results, and thus to go a step further toward a more structured FU definition framework. The contribution of Functional Analysis seems promising.

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