Fuon theory - Beyond comparing oranges with oranges

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INTRODUCTION

To be able to derive practically valid conclusions from a Life Cycle Assessment (LCA), results need to refer to a comparison of elements that are considered to be somehow equivalent (i.e., they have the same Functional Unit (FU), according to ISO, 2006). Similar products tend to be considered as equivalent, but as differences get bigger, the conclusions that one can derive from them become more and more subjective, and diverge more and more from what is stated in ISO. For products in which the main functionality is different, the authors (Collado-Ruiz & Ostad-Ahmad-Ghorabi, 2010a) presented the concept of Life-cycle Comparison Product Families, LCP-families in short. This allowed to scale similar products based on some basic functional parameters.

However, most times practitioners do not define their FU in technical terms, or if they do, they use inconsistent terms and parameters. For that matter, the authors also developed the concept of Functional Icons, fuons in short (Collado-Ruiz and Ostad-Ahmad-Ghorabi, 2010b).

This paper presents a general introduction to the concept of fuons and how to use them, both in general to phrase FUs and in particular for LCA-scaling through LCP-families. The last section presents an outlook on research in fuons, with some

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proposals on the directions and potential for this concept as part of generating a common functional structure concept for products.

FUONS: WHAT AND WHY

A fuon can be defined as an abstraction of a product, based on its essential function flows and additional functions or features. For each functional flow - a process in which a flow of matter, energy or information is affected in one way or another - one fuon should exist. For example, in the case of containing and protecting matter, one fuon would define all products that serve the purpose - generally the main purpose - of storing matter. This fuon is presented by Collado-Ruiz and Ostad-Ahmad-Ghorabi (2010a) with the name of Container Fuon.

All products described by one particular fuon should have their FU phrased in a relatively homogeneous way, that is, using the same physical parameters to define the main functional flow. In the example case of the Container fuon, such parameters would be "weight supported" and "number of storages". This means that both a paper bag and a truck container can be defined by those parameters. These parameters, that physically describe the product, are called physical FU parameters, or FUp^{p}s.

Of course, a complete FU would not only be defined by those functional flows, but would also specify what extra conditions or traits the product needs to comply with, to be comparable with the product at hand. For this reason, each fuon is also described by a number of constraint parameters, called constraint FU parameters, or FUp^{c}s. An example of a fuon is presented in Figure 1, showing both its FUp^{p}s and its FUp^{c}s.

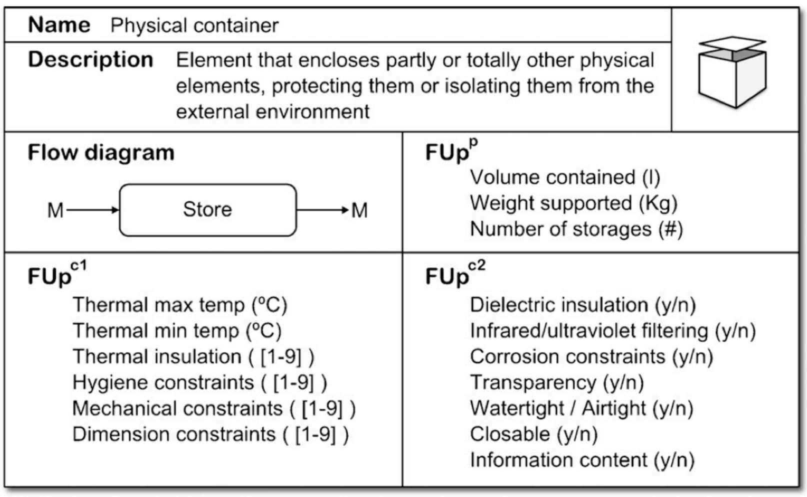

Figure 1 - Container Fuon, from Collado-Ruiz and Ostad-Ahmad-Ghorabi 2010b

- Separating the development and use of fuons: currently, any LCA practitioner must develop a complete FU for the product, often resulting in incomplete or inconsistent FUs. By using fuons, one person - generally a researcher or consultant - would develop the fuon once, out of information from multiple products, and practitioners just have to select the Fuon and answer the simple questions that the fuon includes.

- Facilitate comparison of environmental traits: since the initial purpose of grouping products together was an environmental comparison, fuons configure the product in the right way to make relevant environmental comparisons, and set strategic targets even if there is no specific information about products with that particular size or FUp^ps.
- Encourage innovation by grouping together products with the same functional flows, even if they are perceived as very different products. Strategies that are relevant to reduce the environmental impact - or increase the efficiency - of one particular product represented by the Fuon are bound to be relevant as well for those with similar FUp^cs, if not by all the products represented by the Fuon.

HOW TO USE FUONS

In contrary to their development, the use of fuons is quite simple. Each fuon represents one functional flow. Thus, to use a fuon correctly, one has to define the main functional flow of the product being investigated first. In case of multi-functional products with multiple functional flows co-existing, a fuon is needed to represent each of the functional flows.

The main functional flow is key to different parameters that are substantial elements of the fuon. For their correct application it is important to understand the difference between how the two types of parameters in a fuon work. While FUp^ps are used for scaling - as will be presented in the next section - FUp^cs serve the purpose of clustering or selecting the products that will be most similar to the product being designed, not only in their main function, but also in additional properties that it must attain. Fuons are developed in order to cover as many products as possible, but within the family FUp^cs can serve to select those products with a closer environmental performance - or of other sorts. The parameters that are specified become part of the FU, but not necessarily serve the purpose of scaling. That is why it is possible to have even dichotomies (yes-no parameters), since they serve the purpose of selecting.

The only thing the user of fuons has to do is to select the fuon that best represents the product, and then define those FUp^cs that are also part of the product's PDS. However, if used with a database of products (like containers on Collado-Ruiz and Ostad-Ahmad-Ghorabi 2010a), leaving some of the FUp^cs undefined will prompt the user to include in the analysis a number of products which otherwise would have not been considered comparable.

HOW TO DO LCA SCALING

Collado-Ruiz and Ostad-Ahmad-Ghorabi (2010a) proposed a new form of grouping products: that of product families for LCA comparison (or LCA-comparison product families, LCP-families). This concept spawns from the idea of product family and of grouping products with common traits together but adapts to the purpose doing this from environmental point of view. Therefore, LCP-families are those of products of

comparable environmental traits. Fuons are used, as was presented in the previous section, to define such groups.
From an ethical standpoint, higher performance is normally allowed higher impacts, and the correlation generally exists. For that matter, to compare these products to each other, and more specifically to a new product being designed, one would need to scale them. Since FUp^ps are defined specifically for that purpose, one can scale all the products in the LCP-family to those values of FUp^ps of the new product. This would create a number of equivalent - or scaled - comparable products that the new product would need to match.
For setting the targets Collado-Ruiz and Ostad-Ahmad-Ghorabi (2010a) propose to use reference ranges, defined as those in which products can be assessed as to their better or worse environmental performance in comparison to competing products, independently to their technology. For example, reference ranges could be those ranges of environmental performance in which the best performing 5% are to be found.
A range can be calculated where an average environmental impact can be given for family as well as a lower and higher range. The reference range proposed usually includes 95% of the benchmark products. Hence, to develop a product that is environmentally performing better than 95% of the bench, its environmental impact has to be lower than the lower range of the reference range. Should the impact be higher than the higher range, the product is performing worse than 95% of its bench.

OUTLOOK TO THE FUTURE

The development of fuons is still in its early stages, since the base of fuons available is still low. However, the approach presents a promising possibility for the development of a functional base for the phrasing of products, or even for the functional description of products in general.
The critical future steps in fuon theory include the development of more fuons. So far, three fuons are already fully developed: one for physical containers, the logistic-intenisve fuon and the digital storages fuon Ostad-Ahmad-Ghorabi et al 2013). A systematic framework is being developed to allow the systematic development of fuons. Ostad-Ahmad-Ghorabi (Ostad-Ahmad-Ghorabi 2010) stated that the total amount of fuons is strictly limited, which is one of the main positive facts of having such a methodology.
What needs to be explored in future is the combination of fuons in multi-functional products. It is of essential interest to analyze the respective algorithms of LCP-families and fuons in case of addition of several fuons, since most of the work until now is based on assumptions that have been only tested for the low fuon base currently available.
Additionally, experience has shown that engineering designers will only accept new tools and methodologies in their work process if it does not add significantly to their daily workload. The application of fuons has to be simplified as much as possible. Integrating fuon theory in CAD or PDM systems can help to spread its application among engineering designers. It is therefore interesting to investigate more in the interaction of fuons and practitioners.
Furthermore, the maximum potential of fuons can be obtained if large quantities of data are handled (not only in the number of fuons to model products, but also in the number of products in the database). For that matter, a considerable effort lies ahead

in populating such a database and making it available for practitioners. For the moment, companies can develop internal databases, but the authors are working in progressively expanding and making available this information.

Modeling fuons through common databases also opens up a number of potential study lines that can be addressed, including modeling of inventory information, statistical analysis of trends, or artificial intelligence to allow computers to make improvement proposals based on similarity rates and environmental performance of other elements in the database.

Finally, one can interpret fuons in general as an evolving ontology for FUs, or for functional descriptions in general. The behavior of this ontology, together with a mapping of how it can interact with other more powerful ontology tools, is an area to explore as further research.

Altogether, fuons can constitute an enabling concept for the environmental assessment of products, or their functional modeling. The authors are working in this direction, but are also open and willing to collaborate with other researchers in the progressive development of this area.

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