Développement durable

Anne Ventura
(Dir.)

Challenges of functionnality for eco-design

Crossed visions of functionnality from various disciplines

EcoSD Annual Workshop 2014

MINES ParisTech

Presses des Mines

Anne Ventura, (coord.), *Challenges of functionality for Eco-Design, Crossed visions of functionnality from various disciplines,* EcoSD annual workshop 2014, Paris, Presses des MINES, collection Développement durable, 2016.

60, boulevard Saint-Michel - 75272 Paris Cedex 06 - France
presses@mines-paristech.fr
www.pressesdesmines.com

ISBN : 978-2-35671-421-3
Dépôt légal : 2016
Achevé d'imprimer en 2016 (Paris)

Challenges of functionality for Eco-Design

Crossed visions of functionnality from various disciplines

EcoSD annual workshop 2014

Collection Développement durable

Dans la même collection :

Isabelle Blanc
EcoSD Annual Workshop

Junqua Guillaume , Brullot Sabrina
Écologie industrielle et territoriale

Association Événement OSE
Énergie, citoyens et ville durable

Labaronne Daniel
Villes portuaires au Maghreb

Emmanuel Garbolino
Les bio-indicateurs du climat

Bruno Peuportier (dir.)
Eco-conception des ensembles bâtis et des infrastructures

Bruno Peuportier (dir.)
Livre blanc sur les recherches en énergétique des bâtiments

Association Événement OSE
Smart grids et stockage

Ouvrage coordonné par Gilles Guerassimoff, Nadia Maïzi
Smart grids. Au-delà du concept comment rendre les réseaux plus intelligents

François Mirabel
La Déréglementation des marchés de l'électricité et du gaz

Fabrice Flipo, François Deltour, Michelle Dobré, Marion Michot
Peut-on croire aux TIC vertes ?

Benjamin Israël
Quel avenir pour l'industrie dans les places portuaires ?

Association Événement OSE
Eau et Énergie

Ouvrage coordonné par Bruno Duplessis et Charles Raux
Économie et développement urbain durable 2

Ouvrage coordonné par Gilles Guerassimoff, Nadia Maïzi
Eau et Énergie : destins croisés

Christophe Gobin
Réussir une construction en éco-conception

Ouvrage coordonné par Jean Carassus et Bruno Duplessis
Économie et développement urbain durable 1

Ouvrage coordonné par Gilles Guerassimoff et Nadia Maïzi
Carbone et prospective

Peuportier Bruno
Éco-conception des bâtiments et des quartiers

Ouvrage coordonné par Gilles Guerassimoff et Nadia Maïzi
Îles et énergie : un paysage de contrastes

Coordination :

Anne Ventura

Challenges of functionality for Eco-Design

Crossed visions of functionnality from various disciplines

EcoSD annual workshop 2014

Table of contents

Foreword

As president of EcoSD (Ecodesign of Systems for a sustainable Development), I am very proud to present EcoSD, the association which organizes and supports financially this annual workshop and its associated publication since 2013.

EcoSD network is a French association whose main objective is to encourage collaboration between academic and industrial researchers so they may create and spread advanced and multidisciplinary knowledge in the eco-design fields at national and international levels. Several actions are proposed by the EcoSD network with the support from the French Environment and Energy Management Agency (ADEME), from the French Ministry of Higher Education and Research as well as the Ministry of Industry:

- Structuring EcoSD research activities in France to take advantage of the expertise from more than 300 members of this research network,
- Developing knowledge among researchers regarding the field of eco-design, particularly better training of PhD students by organizing relevant training courses over different themes in eco-design,
- Elaborating new methods, new tools and new databases to achieve complex systems design, compatible with the principle of sustainable development,
- Initiating the EcoSD label to acknowledge the quality and inclusion of sustainable development in trainings, research programs, research projects and symposiums,
- Helping interactive collaboration between researchers and industrial partners through the organization of quarterly research seminars in Paris and an annual workshop.

Around 50 researchers from industry, academia and governmental institutions participated in the 2014 workshop on “Functionality and Eco-design” and had the opportunity to exchange with experts.

The associated publication contains a synthesis of the main contributions presented during this workshop.

I am very grateful to the coordinators (A. Ventura and S. Lepochat) for the perfect organization of this workshop held in Nantes in March 2014. I also thank all the speakers for the quality of their presentation and the fruitful exchanges they permit.

Dominique MILLET
President of EcoSD

Introduction to the workshop

Anne VENTURA[1], Stéphane LEPOCHAT[2]

[1] Université de Nantes, laboratoire GeM, chaire génie civil éco-construction
[2] Evea, Nantes

1. Context and stakes of the workshop

The notion of function in eco-design can have different meanings, according to the discipline (engineering, economy, sociology), and according to the life cycle step. When a product is conceived, eco-designing imposes to foresee the use and end-of-life phases. However, there are differences between the "expected functions", and the actual "usage" of products, that could be compared by analogy to the difference between "supply" and "demand" in economy.

This gap between function and usage could be explored to improve environmental performances of products because adjusting the function is a performance axis by itself, as well as to better define comparison basis between similar (but different because multi-functional) products.

This problematic is transversal to eco-design: eco-usage, functional economy, Life Cycle Assessment (functional unit and consequential LCA)… It can be resumed by the following key questions: How to define functions? How to predict and quantify functions, utilities and usages? How to compare complex objects?

A workshop was held in Nantes on 2014, on behalf of the EcoSD French national network. Its objectives were to cross different visions from different disciplines that could possibly lead to a common frame.

The schedule of the workshop was defined in three parts: a first part helped framing the question by various examples in the fields of food and building sector, a second part was dedicated to methodological aspects involved into defining functionalities, and a third part declined new approaches used in recent studies.

2. Program of the workshop

Framing the question

N. Antheaume (Institut d'Administration des Entreprises, Université de Nantes) "Unexpected functions: case of short distribution channels in agriculture"

H. van der Werf (INRA Rennes) "Economic value as a functional unit for environmental labelling"

S. Morel (Mines ParisTech) "Collaborative LCA (co-LCA) to rethink functionalities equivalence of innovative systems"

C. Gobin (Vinci construction) "Functionalities of buildings, the notion of signature"

T. Gidel (Université Technologique de Compiègne) "From function to functionality, from engineering to economy"

J. –C. Boldrini (Université de Nantes) "Functions, value criteria and usage: methods in value management, innovation marketing, strategy and innovative design."

Various frames for characterization of functions

D. Collado-Ruiz and H. Ostad-Ahmad-Ghorabi (Universidad Politécnica de Valencia, and Ferchau Engineering GmbH) "Fuon theory: beyond comparing oranges with oranges"

A. Ventura (chaire génie civil écoconstruction, laboratoire GeM, Université de Nantes) "Function, economic actors and life cycle."

B. Yannou (Ecole Centrale Paris) "Quantification of utilities of products in usage situations."

Some propositions for new approaches

F. Laurent (Akajoule – IRSTEA) "Systemic approach of territorial biogas plants to define relevant functions for their environmental assessment."

N. Tcherchian (SUPMECA Toulon, SUPMECA Paris) "The influence of the level of definition of functional specifications on the environmental performances of the complex system. The Eco CSP approach."

Unexpected functions: the case of local supply chains in agriculture

Nicolas ANTHEAUME, Nathalie SCHIEB-BIENFAIT

LEMNA and IEMN-IAE, Université de Nantes

1. Introduction

In 2008, the French government initiated a roundtable for the environment, named *"Grenelle de l'Environnement"* in which stakeholders from the world of business, government, NGOs, and research, were invited to define a national agenda for the environment. A law for the environment (la loi Grenelle 2) was voted in 2012 so as to enforce some of the proposals from this roundtable. This created a context which encouraged many local governments to develop local sourcing strategies for the school restaurants which they manage.

We will present a research whose aim was to evaluate the impact of a project in which the central kitchen of a major town experimented with purchasing free range chickens from a selection of local farms, instead of industrial chicken legs or breasts from a wholesaler. Comparing the two products led us to try and define their attributes and this raised the question of the unexpected functions which they fulfilled, but difficult to account for. In this article, we will focus specifically on this issue.

The project we are presenting was carried out in 2010 and since then has been repeated every year. In part 1, we will briefly present the participants involved in it, as well as the constraints they faced in order to take part in this experiment. In part 2, we will describe how these constraints were overcome to make the experiment successful. In part 3, we will show that if, despite a cost and an environmental disadvantage, the project was pursued until today, it is because the initial experiment revealed the unexpected functions fulfilled by free range chickens and what made them different from industrial ones. We will conclude by showing why, despite this specific success, these unexpected functions are still difficult to take into account in decision processes.

2. The stakeholders involved and their constraints

The town of N made it one its priorities to develop responsible sourcing strategies. The head of its purchasing department received a clear political mandate to do so. Developing local sourcing for school restaurants was one of its projects. However there were budget constraints to respect. Furthermore, for central and local government organization, French law forbids that the local character of a product be turned into a criteria in public calls for tenders. However environmental criteria are allowed and hopes were being raised that local sourcing projects could yield to lower environmental impacts.

The school restaurant division of the town of N is an organization which runs 89 restaurants. It has a central kitchen which prepares the meals, stores them and dispatches them to the school restaurants. Every school day, 12 000 meals are prepared and served; 38 people work in the central kitchen and approximately 700 people are dispatched in the school restaurants of the town. The central kitchen can be described an industrial processing unit with very limited transformation capabilities. For instance it is not equipped to wash, peel and cut vegetables. Nor is it equipped to cut meat. Thus, the vegetables which it buys have already been transformed and are either canned, frozen or sealed in air-tight bags. The meat which it buys has already been cut into portions and is ready to cook. When it buys 30 day industrial, chicken, it is either chicken legs or chickens breasts, with a pre-specified weight which the wholesaler can respect with an accuracy of up to two grams.

C44 is a cooperative which was created by a Trade Union representing the interests of small farmers. It acts locally. It provides training to small farmers and consultancy services to local governments willing to develop local sourcing initiatives. It has initiated many projects in this field with the long term aim of encouraging new farmers to settle by providing stable business opportunities through the local supply chain. However it faced constraints in matching supply with demand. The first one was to identify farmers with enough production capacities to take part in the project. The second one is that the production of the farmers was not standard. Each of the farmers involved had different protocols to raise and feed the animals. All farmers had in common the number of days after which the chickens were being slaughtered: 130 days, as compared to 30 with industrial chicken. In the end there was a great variability in the weights of animals, within each farm and between farms. The third constraint was that these farmers did not have the ability to transform their production. They were not equipped with facilities to cut, peel and package vegetable, or with the equipment needed to cut meat on an industrial scale.

3. How constraints were overcome

With such constraints, in order for the project to be successful, many factors were activated. We will present the most important ones.

Perhaps the most important element is that the project was presented as an experiment. This was accepted at the outset by all the parties involved. It was agreed that it would be a test the results of which would help study how such a project could be scaled up at a later stage and become a business as usual operation. This had powerful implications. First, this experimental status meant the possibility to act out of the boundaries imposed by French law on public tenders for government organizations. Second, it enabled giving the project a dimension which was compatible with the production capacity of the farmers involved. Eight school restaurants, serving 1 200 meals were selected. Third, it focused the attention of participants on making the project successful rather than being frightened by the constraints and their implications. Psychologically, participants did not feel they had any obligations after the experiment and this made compromises easier to find.

The second element is that all the parties involved made a genuine effort to understand each other's work and constraints. Based on that mutual knowledge, each participant had a precise idea of what could be done in order to help other participants removing their own constraints.

The third element is that, locally, two small scale transformation structures, which had been created as cooperatives, by groups of small farmers, were available: a small scale cooperative slaughterhouse and a meat cutting workshop. They had excess capacity available and saw this experiment has an opportunity to better absorb their overhead costs. At a later stage, for further "experiments", a large cooperative, selling certified red label chickens agreed to join the project and allowed the use of its slaughterhouse. This enabled small farmers to sell whole chickens to the town of N's school restaurants.

All in all, the experiment was a success because the participants, who had never worked together before, with seemingly incompatible constraints, managed to set up a successful project which still goes on today on a regular basis.

However, right from the outset, a difference in price between the industrial type chicken and the free range chicken was expected. It was expected that this would present difficulties. There was hope that an analysis of environmental impacts would give local supply chains an advantage and thus give local sourcing an advantage. As we will briefly explain in the next part, this was not the case.

Despite this, the project carried on. The school restaurant division accepted to make budget cuts in other areas and the town of N also accepted some of the extra costs that this project would entail. This happened because when analyzing the outcome of the initial experiment, unexpected functions of the local supply chain project came to light, which made the project both politically and economically acceptable.

4. The unexpected functions of local chicken

A first level analysis revealed that free range chickens, sourced from local farmers, were 150% more expensive than industrial chicken legs or breasts. Certified red label chickens which were used later as an additional source of supply proved to be "only" 100% more expensive.

Initially we thought that an analysis of environmental impacts would counterbalance this cost disadvantage. However a preliminary analysis revealed that this would not be the case. Short supply chains generate transport between participants for relatively small amounts of goods being transported. Also, per unit, free range chickens use more space than industrial ones and require more inputs. Also, since they are produced in smaller quantities, they do not benefit from scale economic savings in the same way as industrial ones.

However the local sourcing of chickens was continued. A combination of budget cuts in other areas and extra financial resources made this possible because the experiment revealed the following differences and unexpected functions that an industrial chicken did not have.

To start with, the two products being compared had fundamentally different characteristics. The school restaurant division purchased only industrial chicken legs and breast, compared to pre-cut whole free range chickens. Both chickens should have been compared on the same basis. From a cost perspective it probably would have given yet a further cost advantage to industrial chickens. From an environmental perspective, taking into account whole industrial chickens would have reduced the environmental disadvantage of free range chickens.

Also it was clear from the outset that the two types of chicken being compared were of a different quality and that a price difference would be expected. However, it turned out that the price of free range chicken was equivalent for one meal to that of a veal *sauté* made from industrial meat… thus raising the question of whether it might be advisable, for the same price to serve high quality chicken rather than low quality veal. This put into question what was the exact function of chicken: to specifically provide… chicken, or to be a source of protein in a meal.

It turned out that introducing free range chickens in the menus of school children changed a number of processes at the central kitchen. To start with, the chicken was cooked at lower temperatures, for longer times, which overall translated into energy savings. The chickens could also be delivered, pre-cut, in special baking trays which would go directly in the oven and could also be used for delivery to the school restaurants. This was not the case for industrial chicken legs and breasts which had to be unpacked, transferred onto hobs for high temperature cooking and transferred again into trays before delivery to the school restaurants. Also, every time chicken was on the menu, three persons for half a day were also employed to wash the hobs.

Overall, these adjustments and changes reduced the cost and the environmental disadvantage of free range chicken (less labor, less energy, less water, less dishwashing liquid) but there was still a difference with industrial chicken.

However, as months went by it also became clear that the local free range chicken had attributes which were not taken into consideration in the initial price comparison. It contributed to the preservation of local agriculture by supporting more jobs than the industrial one. To earn approximately the same revenue, and make a living, a farmer can either produce 20 000 industrial chickens or 5 000 free range ones per year. Thus, for the same amount of chickens produced, more farmers are needed for the free range option. These jobs are local. The local sourcing project thus provided potential markets for new-coming farmers. It also contributed to the environmental education of school children as farmers were invited to school restaurants to present their activity and give pupils the idea to raise the question of where their food comes from. This is not possible if the chickens are purchased from a wholesaler, from an unknown destination. Also the school children were not given an environmental message in class (turn of the tap when you brush your teeth, switch off the light when you leave the room,…), and altogether a different subliminal one during lunch (low quality industrial chicken of an unknown origin).

Finally, this project also contributed to the development of local networks as the participants had to discover each other's operations and work together so as to develop local sourcing strategies which did not previously exist.

Needless to say that putting a price on these functions and estimating the environmental impacts of these unexpected functions poses daunting challenges to specialists and we were not able to quantify it within the scope, time and budget of our study. However the case seemed convincing enough for the initial experiment to be continued and to become a permanent project. The school restaurants division has now stopped purchasing industrial chickens and only orders either certified red label chickens from a large local cooperative, or free range ones from local small farmers.

5. Conclusion

However if these unexpected functions were identified, the challenge remains of developing methodologies to quantify them. Furthermore, even if they could be quantified it would still be difficult to include them in decision making processes. The "localness" criterion is still not allowed in government call for tenders. Also, if there is a positive impact on the economy and on the environment, the town of N will not be directly rewarded for spending more public money. Thus the present economic conditions offer few incentives to do so. In the long run this will have to be changed if a project such as the one we described was to be generalized.

6. References

[Antheaume & Schieb-Bienfait 2012] Antheaume, Nicolas ; Schieb-Bienfait, Nathalie, 2012. Circuits courts et économie de proximité : de la confrontation de logiques… à la recherche de compromis. *7e Congrès du RIODD 2012* (31 p.). Nantes.

[Antheaume et al. 2011] Antheaume, Nicolas ; Le Velly, Ronan ; Morael, Patrick ; Offerteli, Patrick, 2011. Comment introduire du poulet fermier paysan en restauration collective individuelle ? *Séminaire LIPROCO (Lien Producteur Consommateur)*, Angers.

Economic value as a functional unit for environmental labelling

Hayo M. G. VAN DER WERF, Thibault SALOU

INRA, Agrocampus Ouest, UMR1069 SAS, Rennes

1. Introduction

In 2009 the French government passed a law on the right of consumers to "sincere, objective and comprehensive environmental information" through the so-called "affichage environnemental", i.e. environmental labelling, of mass marketed products [Vergez 2012]. This information would be based on a product's entire life cycle and consider several environmental impacts, including a carbon footprint. To implement this law, sector and product category rules have been developed, and a voluntary one-year (2011-2012) trial has been conducted, involving 168 companies, 70 of which were agrifood companies.

In November 2013 a commission of the French parliament produced a report, based on this trial, on the interest of environmental labelling [Errante & Saddier 2013]. The report judges that the proposed Life Cycle Assessment (LCA) methodology produces results that are insufficiently reliable, as "the environmental impact displayed is an average value, which is in reality a potential impact rather than a scientific impact. It notes that the impact data result from "conventional choices, lacking a scientific basis", "these methodological choices – functional unit, criteria considered, calculation methods, etc. – markedly affect the variability of the displayed results". Regarding food, the report criticizes the functional units (FU) chosen: 100 g, 100 ml or a portion, as they do not reflect the functions of food. These FU will favor efficient high-input intensive systems and result in higher impact values for products from low-input and organic systems aiming to produce quality products.

This report echoes some of Freidberg's observations [Freidberg 2013] that, for companies LCA "seems too complicated", while as a field "it seems too fraught with conflict and dispute". She points out that "in LCA, methodological debates date back nearly as far as the field itself. They defy resolution partly because LCA's models, like those in fields such as climate science and environmental technology, are inherently unverifiable".

In this text we focus on the choice of the FU. The most common FU for food is mass or volume [Schau & Fet 2008, Roy et al. 2009], so the proposed FU for environmental labelling corresponds to LCA practice. Other FUs proposed for food are nutritional value, area of land occupied, and economic value [Schau & Fet 2008]. The use of nutritional value as a FU is complicated, since food products supply a range of macro and micro nutrients, which is hard to capture. The FU area of land used is quite frequent; it reflects the function of agricultural systems as modes of land use. Economic value has been proposed as to capture "emotional value" of food [Schau & Fet 2008]. Consideration of food quality in the definition of a FU has been limited to nutritional quality. Surprisingly taste has not been considered.

This paper is a contribution to the debate on the most appropriate FU for environmental labelling of food and other consumer products. We explore the effect of the choice of FU on the ranking of agricultural products from production systems of contrasting intensification level (i.e. conventional versus organic agriculture).

2. Materials and methods

The AGRIBALYSE public life cycle inventory database [Salou et al. 2013] contains 130 LCIs of French agricultural products at the farm gate. It was built to support environmental labelling of food products and to assess impacts of agriculture. We used LCI data for organic and conventional pig and broiler and the CML 2001 method to calculate impacts per t of animal live weight at the farm gate and per ha of land occupied. For broilers live weight prices at the farm gate used were 0.85 and 2.70 Euro/kg for conventional and organic, respectively. For pigs we used a dressing percentage of 78% and carcass prices: 1.30 and 2.95 Euro/kg for conventional and organic, respectively. These were used to calculate impacts per 1000 Euro of animal live weight.

3. Results and discussion

When using the FU live weight, organic animals have larger impact values than their conventional counterparts for all impacts examined (Table 1). Although these are data for live animals at the farm gate rather than for transformed products, they illustrate that a mass-based FU favors intensive highly efficient conventional systems over less intensive organic systems that produce less product of higher value.

Per ha of land occupied, organic animals have smaller impacts than their conventional counterparts for both eutrophication and climate change, but production per ha is lower. Organic agriculture thus constitutes a less impacting mode of land use for a given territory. When the FU economic value is used, organic animals have similar or lower values for eutrophication, lower values for climate change and higher or similar values for land occupation.

These results illustrate that the choice of FU is crucial. The FU economic value is attractive, as it considers product quality through the product's price. The large price difference between organic and conventional animals reflects a willingness of consumers to pay more for a product that is perceived to be of better quality (regarding taste, expected benefit on human health, or valuation of the organic production mode). In agriculture, as in other economic sectors, there often is a tradeoff between quantity and quality. A mass-based FU tends to favor products from systems that focus on quantity rather than quality, yielding products of basic quality. An economic-value-based FU will be more favorable to systems producing products of superior quality.

More generally, an economic-value-based FU is very well suited for environmental labelling of any type of consumer product. Basically a consumer has a certain budget to spend; an economic-value-based FU may guide the consumer towards reduced impacts per Euro spent. This reflects a vision of the function of food and other consumer products: they are means that allow consumers to spend their money.

		PRODUCT AND PRODUCTION MODE			
		PIG		BROILER	
PARAMETER	UNIT	ORGANIC	CONVENTIONAL	ORGANIC	CONVENTIONAL
		FU: T OF LIVE WEIGHT AT FARM GATE			
Eutrophication	kg PO4 eq.	31	14	24	12
Climate change	t CO2 eq.	3.5	2.4	2.3	2
Land occupation	m² year	1.06	0.34	0.85	0.27
		FU: ha of land occupied			
Eutrophication	kg PO4 eq.	29	41	28	44
Climate change	t CO2 eq.	3.3	7.1	2.7	7.4
Production	t live weight	0.9	2.9	1.2	3.7
		FU: 1000 Euros of live weight at farm gate			
Eutrophication	kg PO4 eq.	13	14	9	14
Climate change	t CO2 eq.	1.5	2.4	0.9	2.4
Land occupation	m² year	0.46	0.33	0.31	0.32

Table 1: Production per ha of land occupied and impacts of organic and conventional pig and broiler at the farm gate according to three functional units (FU)

4. Conclusion

We recommend the use of a FU based on economic value for the environmental labelling of food and other consumer products.

5. References

[Errante & Saddier 2013] Errante S., Saddier M. 2013. Rapport d'information sur l'affichage environnemental. Rapport no. 1562, Assemblée Nationale. Retrieved from: http://www.assemblee-nationale.fr/14/rap-info/i1562.asp

[Freidberg 2013] Freidberg S. 2013. Calculating sustainability in supply chain capitalism. Economy and Society, published online. DOI: 10.1080/03085147.2012.760349.

[Roy et al. 2009] Roy P, Nei D, Orikasa T, Xu Q, Okadome H, Nakamura N, Shiina T. 2009. A review of life cycle assessment on some food products. J Food Eng 90: 1-10.

[Salou et al. 2013] Salou T, Koch P, Mousset J, Gac A, Gaillard G, van der Werf H. 2013. Methodological choices for an LCI database of French agricultural products. Proceedings of the LCM 2013 Conference. Retrieved from http://conferences.chalmers.se/index.php/LCM /LCM2013 /paper/view/636/234

[Schau & Fet 2008] Schau EM, Fet AM. 2008. LCA studies of food products as background for environmental product declarations. Int J LCA 13 (3): 255-264.

[Vergez 2012] Vergez A. 2012. Display of the environmental footprint of products: French developments in the food sector. Etudes et documents no. 64. Department of the commissioner-general for sustainable development, La Défense, France. Retrieved from: http://www.developpement-durable.gouv.fr/Display-of-the-environmental.html.

The views expressed in this paper are those of the authors and should not be attributed to INRA.

Collaborative LCA (Co-LCA) to rethink functionalities equivalence of innovative systems

Stéphane MOREL[1,2], Franck AGGERI [1]

[1] MINES PARISTECH, Centre de Gestion Scientifique

[2] RENAULT, Alliance Technology Development

1. Introduction

The economic development of companies relies on two pillars: increasing the number of contracts and improving the margin of each contract. One key instrument of this strategy is to innovate. By definition, an innovative product challenges the functions and business models. This generates a real complexity when comparing innovative and classic systems. In this context how could analysts build a reliable comparison of products? And at first how to design the correct functional unit and scope of the LCA study?

This work first proposes a method to check the systems comparability, then to investigate two options to fulfill the equivalence of the systems: the first one is a system extension of the functional unit and the second one is the implementation of the ISO eco-efficiency norm. Both ways are applied and discussed to guide LCA practitioner.

2. Materials and methods

The aim of the methodology developed here is to determine the accuracy of the product comparison for several functional unit proposals. The Danish EPA published a set of guidelines to provide advice and recommendations on key issues in LCA [Weidema 2004]. They propose five key topics to define the functional unit and associated reference flows.

Life Cycle Assessment is both a mathematical model and an approach which requires many structural decisions from the practitioner. Innovative product and services deeply challenge those decisions. After an analysis of the LCA and collaboration frameworks, a new scheme is proposed for Collaborative LCA [Morel 2014]. Collaborative LCA (Co-LCA) is a five steps process (5E scheme). Table 1 below describes it.

COLLABORATIVE LCA [MOREL 2014] APPLIED TO FUNCTIONAL UNITS DEFINITION	DANISH EPA [WEIDEMA,2004]
1/ Explore the innovation peculiarities and detect LCA issues; Tool = Customer survey	A review of existing functional units in the product sector
2/ Engage a collective action with appropriate stakeholders; Tool = Persona	A description of consumer archetypes and expectations/usage from the product
3/ Elucidate the issue with specific tools & events; Tool = functional analysis, emotional needs	A description of the product by its properties
4/ Evaluate the outcomes for LCA & benefits for participants; Tools = system extension and eco-efficiency	Proposal of fairly comparative functional unit and reference flows
5/ Extend toward new LCA routines & enrich partnerships	Recalculation of the results and complete the interpretation

Table 1: Collaborative LCA [Morel 2014] applied to functional units definition

This scheme is applied to propose an appropriate functional unit for vehicle mobility. Customers could not be directly involved, therefore, phase 2 and 3 are based on internal in depth studies of customer segmentation. This method and tools are applied hereafter.

3. Results

This section presents the results for each step of the Co-LCA collaborative scheme.

Step E1- Explore the innovation peculiarities and detect LCA issues

The panel of automotive LCA studies includes 25 publications, from 9 authors or companies across 3 continents (Europe, United States of America, and Asia (Korea)). Then functional units are analyzed according to [ILCD2010] requirements. Four aspects shall be identified and specified in detail. Nevertheless, no study proposes a complete functional unit. The analysis of the four aspects shows a documentation rate for "what" (64%), "how much" (96%), "how long" (20%) and "in what way" (36%). For the well documented item "how much" there is a consensus on the unit (kilometers) but it is observed a wide range of values from 100 000 to 300 000 kilometers. The last item "in what way", shows no consensus at all.

Step E2- Engage a collective action with appropriate stakeholders

Consumer archetypes are constructed for fleet customers, individual customers, company CEO, NGO leader, and public authorities. They are described with socio-demographic characteristics (age, sex, and social class) and their relation to vehicles (usage, dependency). A template is tested and improved throughout several experimentations.

Step E3- Elucidate the issue with specific tools & events

Our proposal is to use Functional analysis and Affinity diagrams to map the product properties. The functional analysis methodology provides a guidance to determine the relationship between the product, its environment and usage scenarios. 17 functions are identified and they are sorted in four groups: Security (e.g. chocks, thief), Performance (e.g. speed, autonomy), Cost (e.g. purchase cost, use cost) and Comfort (thermal comfort, noise, roominess). Affinity diagrams provide a survey where people panels can freely express themselves on the words they associate to emotional needs and propose a hierarchy between them. Those are identified and grouped in four thematic: Environmental friendly, Aesthetic & Personalized, Smart & Fun, and Reassuring. These two approaches are complementary and allow a global functional assessment.

Step E4- Evaluate the outcomes for LCA & benefits for participants

For each property, the workgroup gives an importance level from 1 to 6.

Cost, comfort, esthetic and performance achieve in average similar rating between electric and thermal vehicles. Environment is a clear benefit (+2pts) and reassurance and security are drawbacks (-1pts). Globally, regarding obligatory properties criteria (product function) the vehicles are similar. In this context, the first conclusion is that functional units are equivalent if the last item "in what way" is not considered. This is the state of arts. The positioning properties differ and therefore, to achieve comparable systems, an environmental action shall complete thermal vehicles and reassurance and security shall complete electric vehicles.

Step E5- Extend toward new LCA routines & enrich partnerships

This paper investigates two methods to align functionalities of the reference and alternative product: system extension (battery renting and vehicle range) and eco-efficiency. To contain the costs, increase reinsurance regarding the battery performance, a new business model is build. In this model, the battery will be rented; it belongs to the carmaker and is automatically changed in case of deficiency. This will increase the environmental impact of the system since spare batteries shall be produced. (+ 300 kgCO2eq.).To increase reinsurance regarding the vehicle range, several axes are developed. At first, the navigator displays the autonomy, confirm the travel feasibility and propose charging points. Then a specific eco-driving driving mode is integrated in the vehicle in order to increase the range of the vehicle. This allows compensating the lost functions by providing services, therefore without additional environmental impacts. Finally, an opportunity could be provided to ensure a few number of long range travels, such as a rent car, or train journeys. In this case, the environmental impact is +200kgCO2eq. for 1500 km vehicle and +2 kgCO2eq. for 3,000 km train. An eco-efficiency perspective is also tested. Here the overall functional benefit is evaluated, based on the obligatory and positioning properties. Since those are very linked to the people values and the cultural background, it is very difficult to set weightings between each items. When all weightings are set to one, the sum of the ratings for each energy shows that the reference vehicle could perform 20% better than the innovative solution. In the meantime, the electric vehicle can reduce the carbon footprint [Renault, 2011] by 20% on average and up to 40% in France. In this context, the eco-efficiency ratio (functional benefit / environmental impact) would be in favor of the electric vehicle.

4. Conclusion and limits

The very first conclusion is that both systems are equivalent regarding the state of arts of functional limit definition.

The current use of the functional unit does not ensure full comparability on the qualitative aspects of cars and car parts. This may lead to false conclusion on LCA studies. The new functional unit suggested in this report ensures a better comparability and hence a truer LCA result. The results of the case studies re-calculated in this experimentation confirmed the result of the original calculations; but the impact gap between the products changed, when the qualitative aspects were incorporated into the product system modeling. It is recommended in all case to investigate the functional and emotional properties linked to the system under study. When this is relevant and feasible, they shall be included in the functional unit definition. If not, they shall be discussed during the result interpretation and may add a new perspective to the conclusions.

There are however some limits to be discussed. Affinity diagrams and weightings, at this stage, may not be fully representative. It is proposed to search for theoretical ground and practical techniques in the cognitive and social sciences (Cognitive psychology, Anthropology, Sociology. Linguistics). In this work, the challenge is mainly in the way emotions or cultural and symbolic values can be transferred into a useful language for LCA study. Therefore results are true only for a restricted geographic perimeter and may differ from other countries and stakeholders.

5. References

[ISO 2006], ISO 14040-44:2006, Environmental management - Life cycle assessment - Requirements and guidelines

[ISO 2012] ISO 14045:2012, Environmental management - Eco-efficiency assessment of product systems - Principles, requirements and guidelines

[Reap 2008], A survey of unresolved problems in life cycle assessment, Part 1: goal and scope and inventory analysis, John Reap & Felipe Roman & Scott Duncan & Bert Bras, Int J Life Cycle Assess (2008)

[Morel, 2014]. Morel, Stéphane. L'empreinte environnementale à l'ère de la société collaborative: de l'Analyse du Cycle de Vie comme outil expert à une instrumentation collaborative pour conduire une transition organisationnelle. Diss. Ecole Nationale Supérieure des Mines de Paris, 2014.

[ILCD 2010]: ILCD Handbook: General guide for Life Cycle Assessment - Detailed guidance

[Weidema 2004], The Product, Functional Unit and Reference Flows in LCA, Bo Weidema, Henrik Wenzel, Claus Petersen, Klaus Hansen, Danish EPA Environmental News No.70 (2004)

[RENAULT 2011], Fluence and Fluence Z.E. Life Cycle Assessment; https://group.renault.com

The building signature: characterization and implementation in construction processes

Christophe GOBIN, Stéphanie CHEVALLIER

VINCI Construction France

1. Introduction

With the development of initiatives in terms of sustainable development, all the construction sector professionals agree on the need for a comprehensive and simple object to clearly assess the buildings sustainability. In this field, Life Cycle Analysis (LCA) proves indisputably a powerful method. However, this approach can suffer from a lack of suitable data or benchmarks adapted to a regional context. Moreover, interpretation of raw LCA results is hardly accessible for non-specialist stakeholders. To overcome these features, a comprehensive and understandable sustainability labelling is needed. To be efficient, it must satisfy five requirements:

1. This label has to be clearly understandable by all the stake holders, at first sight.
2. It must correspond to a common framework for all the stake holders. A commissioning phase must especially be planned in order to verify that the performances are conform to the initial program.
3. This label accounts for all the building performances over its entire life cycle. These performances must be clearly defined by the contracting authority, according to realistic scenarios regarding occupancy, water and energy use. Those scenarios must reflect the user behavior as closely as possible.
4. This label must be completed by a summary form, that precise the targeted nominal performances and the occupation mode over a defined period. This step corresponds to the definition of the functional unit.
5. The label must meet all the efficiency criteria, i.e. use performances valorization and environmental impact reduction over the entire building cycle.

The building signature concept has been developed to meet all these criteria.

2. Description of the concept

Principle

The building signature is designed to fit into the project scheme, whatever assessment method is used to define its specifications (Figure 1). Key element of the construction process, it creates a link between the owners to the end users. Especially, the signature must display performances that can be quantified and verified later by a commissioning process. In this way, the signature will actually contribute to sustainable development.

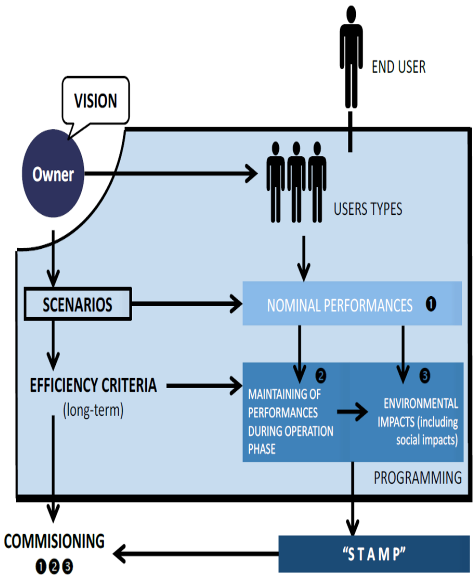

Figure 1: The building signature concept

The signature is meant to express the intrinsic building properties. Thus no one could claim ownership for it; it aims at being seized by any organization. It can thereby be considered as a base for further development of any label by a third party, which can enrich the approach by any criteria.

Core indicators

The signature has to convey the building intrinsic properties at a given time. The purpose is to provide comprehensive information on the building sustainability, including environmental, social and economic performance. The signature concept proposed here is define by 12 core indicators, which can be classified in two groups (Table 1):

- the impact indicators, which quantify the building environmental impacts in a multi-scale approach, from the local to the global scale
- the anthropogenic indicators, which evaluate the building program quality with respect to the final user demands.

The Energy, Water, Natural resources, Waste, GWP and Eco-toxicity indicators all derive from Life Cycle Analysis (LCA), according to the standards [ISO 14040 1997]. Besides, the five following additional criteria are included within the signature:

- the Spatial Comfort, which directly derives from the building geometrical characteristics
- the Thermal Comfort, which results from dynamic thermal simulation
- the Operation Cost, which comes out an economic analysis, such as LCC
- the Flexibility, which is evaluated by inquiring if a change of use or structure is easily possible, given the nature of partition walls or heating management system for example
- the Amenities indicator, which is based on the inventory study of the conveniences in the building area.

	Indicator n°	Name	Definition
Impact indicators	I1	CO_2	Global Warming Potential (100 years), obtained by adding the contributions of all emitted greenhouse gases [t $_{CO2\ equiv.}$]
	I2	Energy	Primary energy consumption, cumulative energy demand including fossil, nuclear and renewable energies [GJ]
	I3	Water	Fresh water consumption [m^3]
	I4	Waste	Final waste generated by the building, classified into 3 categories: inert, hazardous and non-hazardous waste [dm^3]
	I5	Biodiversity	Final damage to nature biodiversity due to eco-toxicity, expressed in Potentially Disappeared Fraction of Species [PDF.m^2.$year^{-1}$], or aquatic eco-toxicity potential (midpoint) [m^3 of polluted water].
	I6	Natural resources	Depletion of natural (mineral and fossil) resources [dimensionless]
Anthropogenic indicators	I7	Health	Final damage to human health expressed in Disability Adjusted Life Year [DALY], or human toxicity, expressed in mass of human body contaminated by the pollutants over a specified period [kg].
	I8	Spatial comfort	Available area per inhabitant [m^2/person].
	I9	Thermal comfort	Indicator of thermal discomfort during summer period, expressed in number of hours beyond an admissible temperature level [dimensionless]
	I10	Operation cost	Cost of the operation phase, including building component maintenance, energy bills, etc. [€/person or €/person/m^2].
	I11	Flexibility	Rate conveying the flexibility of the building, regarding its structure and use [dimensionless]
	I12	Amenities	Rate conveying the availability and proximity of public services, hospital, stores, leisure community centers around the building, considering a 5 km perimeter [dimensionless]

Table 1: The 12 signature core indicators

The regional context is a key factor in the signature concept. Depending on the countries, or sometimes the region, the local specifics (climatic conditions, building typology, users' customs and lifestyles or technology choices, etc.) can be very different. Furthermore, they strongly impact on the building characteristics. For this reason, the building signature is always compared to the mean regional level. Another important feature is the progressive improvement approach. That is why the building signature is designed to be periodically updated, for instance every 5 years.

The signature is based on three key principles:

- the environmental impacts of a building are meaningful only if they are correlated to the
- operation of the building
- the building performance has to be contextualize at a regional level
- the building is more than an immobile object, it has to be considered as a system that evolves along the time.

Graphical representation and interpretation

The quantitative assessment of these 12 indicators summarizes the so called building signature. Then, results are graphically represented by radar chart (Figure 2).

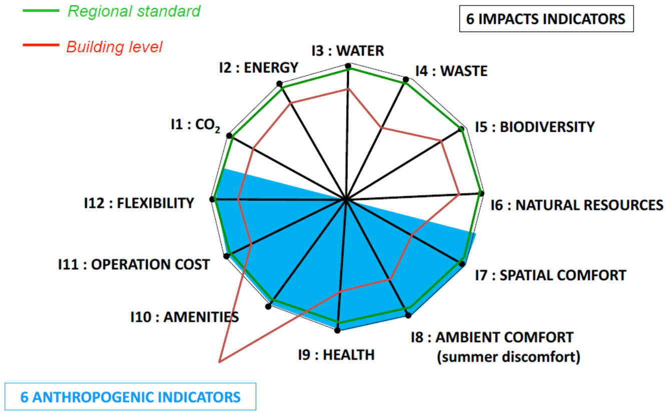

Figure 2: Graphical representation of the signature – The radar chart

Each indicator is considered as better than the regional standard (red line) if it is closer to the center of the radar than the mean regional level (green line). Consequently, the smaller the area of the building radar, the more sustainable the building is. The radar area thus stands for an economic performance rating, allowing a quick visualization of the building value (Figure 3): in this way, the economy refers to the right way to use resource in a construction process, both material and financial ones. This comprehensive graphical tool aims at being an efficient element to assess the building sustainability and communicate with all the stakeholders in the construction process (owner, user, consultant, etc.).

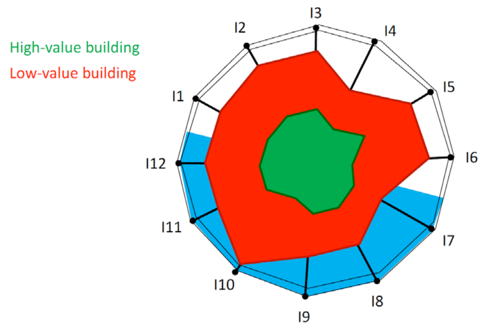

Figure 3: Signature of a high- and a low-value building

3. Integration of the building signature in the sustainable building process

The sustainable building process

The sustainable building process can be divided into 6 steps, described by the road maps developed by Häkkinen and Nykänen within the SuPerBuildings European project framework [Häkkinen & Nykänen 2012]:

1. Sustainable customer briefing
2. A. Sustainable programming
2. B. Sustainable bidding
3. Sustainable preliminary design
4. Sustainable implementation
5. Sustainable use and maintenance.

The building signature concept can be fully integrated within this sustainable building process, since it is involved in two fundamental steps:

- the sustainable programming phase
- the sustainable use and maintenance phase, which considers commissioning aspects.

3.1. The signature contribution to the programming

At this stage, precise objectives must be stated: a clear strategy is defined by the owner to achieve quantified decreased environmental impacts. To address each environmental and anthropogenic indicator, background information and data are required, to build a database of buildings or concepts references. Pertinent examples should be chosen in the same region and in the same typology of use. The signature core indicators could be used by as a framework for the assessment of those references. The mean regional level, corresponding to the building activities, must also be assessed according to the 12 signature indicators.

When dealing with the core indicators, a first "programming radar chart", describing the building signature according to the program, must be drawn. Especially, realistic scenarios of occupancy, water and energy use, must be specified to reflect the end user behavior. Depending on the owner vision, several levels of performances may be targeted. Those options can be expressed by terms of decreasing the level of each indicator by 10%, 20% or more, compared to the regional level.

3.2. The signature contribution to the commissioning

At this stage, precise objectives must be stated: a clear strategy is defined by the owner to achieve quantified decreased environmental impacts. To address each environmental and anthropogenic indicator, background information and data are required, to build a database of buildings or concepts references. Pertinent examples should be chosen in the same region and in the same typology of use. The signature core indicators could be used by as a framework for the assessment of those references. The mean regional level, corresponding to the building activities, must also be assessed according to the 12 signature indicators.

When dealing with the core indicators, a first "programming radar chart", describing the building signature according to the program, must be drawn. Especially, realistic scenarios of occupancy, water and energy use must be specified to reflect the end user behavior. Depending on the owner vision, several levels of performances may be targeted. Those options can be expressed by terms of decreasing the level of each indicator by 10%, 20% or more, compared to the regional level.

4. Conclusion

The proposed methodology is a multi-criteria approach of sustainability, considering environmental, financial and use performances indicators. This concept comes with a clear graphical representation, a radar chart, which permits to easily visualize the building sustainability level and position it in comparison with an average regional level. The progressive improvement approach is also an essential feature of the signature that is why it is meant to be periodically updated.

Carrying the intrinsic building properties, the signature concept is meant to be seized by any organization. Any third party can use it to develop its own label. It is designed to be a step towards a European coherence for a common assessment tool.

5. References

[Frischknecht et al. 2007], R. Frischknecht et al., Overview and methodology, final report EcoInvent v2.0 n°1, Swiss Centre for Life Cycle Inventories, 2007.

[Häkkinen & Nykänen 2012], Häkkinen and Nykänen, Recommendations for the use of sustainability indicators, SuPerBuildings Task 6.1 deliverable, 2012.

[Hongois & Roesslinger 2012], S. Hongois, G. Roesslinger, Results of the French case study – The ENSTA Students Residence, SuPerBuildings D7-2 deliverable, 2012.

[ISO 14040 1997], ISO (International Organisation for Standardisation): "14040 – Environmental Management – Life Cycle Assessment – Principles and Framework, EN ISO 14040, 1997.

[Peuportier et al. 1990], B. Peuportier, I. Blanc Sommereux, Simulation tool with its expert interface for the thermal design of multizone buildings", International Journal of solar Energy, vol. 8, 1990.

[Polster et al. 1996], B. Polster, B. Peuportier, I. Blanc Sommereux, P. Diaz Pedegral, C. Gobin, E. Durand, Evaluation of the environmental quality of buildings – a step towards a more environmentally conscious design", Solar Energy, vol. 57 n°3, 1996.

Functional analysis and functional economy: close and yet so far?

Thierry GIDEL, Frédéric HUET, Justine BISIAUX

University of Technology of Compiègne, COSTECH laboratory, Compiègne, France

1. Introduction

This paper proposes a clarification of the relative positioning of functional analysis (FA) and functional economy (FE), two contemporary design and engineering practices. The reader will be able to rapidly form an idea, albeit an approximate one, of the ambiguity which exists between the notions of the relative proximity or distance of the two practices

On the one hand, there is a strong link between FA and FE in terms of semantics or terminology. The function, as the point of congruence of these two approaches, underline the assumption that the value of an offer is mainly due to the function provided to a user. Moreover these methods contribute to the spreading of sustainable production models. FA and FE may provide leverage for integrating sustainable development in competitive production systems. Whether as a support tool for eco-design in FA, or as a service-based valuation for FE, they together contribute to the transition towards sustainable production systems, alongside circular economy, LCA, industrial ecology, frugal economy and other collaborative economy models.

On the other hand, some elements show a differentiation between these two approaches. The first point is that the objective of the approaches is not identical. FA contributes to the design process, anchoring the function in a tool designed to renew the product design process. FE is characterized by a more comprehensive and multidimensional concept used to develop economic or business models, anchoring the function in a tool that would ensure consistency between the productive, organizational, economic and financial dimensions. There is thus a potential complementarity between these two approaches: FA refreshes our approach to the technical dimension of the activity while FE gives us a renewed grasp of its economic and organizational dimensions. We feel that it is important to make this initial distinction, even if it may seem rather artificial and reductive insofar as the dimensions are in constant interaction. The material anchorage of those methods is more discordant. On the one hand, while focusing on the function, FA favours a strong link between function and the material good. With all the precautions that this implies, we can notice that all the examples mentioned in Wikipedia on functional analysis explicitly refer to material goods (pens, lawnmowers, cars, rockets, etc.). Conversely, FE does not immediately subordinate economic models to a material component. This is reflected again in emblematic examples of FE: Michelin selling kilometers, Autolib mobility solutions…

Just like many of these introductory elements, this product/service duality may seem reductive. This is precisely the point that we wish to clarify in this contribution. We aim at clearly identifying convergences/divergences or complementarities/oppositions which may exist between these two approaches. This paper also aims at exploring implications of reasoning in terms of function rather than concentrating on products.The goal, whether it is for FA (product design) or FE (business model design), is to initiate reflections from a study of the functions to fulfil. In this aim, we will distinguish two levels of analysis, positioning each of these steps on two different planes.

First, we will confront and compare the two approaches on a normative level. Namely, what are they intended for? Which projects and conceptual foundations are embodied in these methodologies? In a normative method, the objectives are approached through the design and examination of « ideal » models, or by considering the potential of these two approaches.

Next, we will compare those methods on a more pragmatic level. How are they implemented? What results do they produce? And we will see that this pragmatic level often appears as a degraded form of the normative one. This is due to difficulties in overcoming the "reasoning forces" of industrial models centred on the production of material goods, for both FA and FE methods.

These leads us to conclude that FA and FE are two approaches with great potential but this potential is not always fully exploited during implementation.

2. The functional promises of FA and FE

Renewing and enhancing the uses

The main goal of this first part of the analysis is to evaluate the objectives of these two practices from a normative point of view. In a normative approach, we consider the pursued objectives from the design of « ideal » models, or the potential of these two approaches. To identify these « ideal types », our study will be based on the different elements of prescription and standardization that have been produced as part of works that integrate these two approaches.

The design literature and industrial standards state the criteria for the categorization and prioritization of different functions (Pahl, Beitz, Feldhusen, & Grote, 2007; NF EN 1325-1:1996). In order to make a consistent comparison, this paper focuses on the service function or main function that allows some of the users' needs to be satisfied. The common objective is to identify and focus on functions to design a product (material goods or services) that satisfies users' needs (C. C. Chen & Chuang, 2008; Lee & Huang, 2009; Matzler & Hinterhuber, 1998; Xu, Jiao, Yang, & Helander, 2009) and therefore provides use value.

This FA starting point is very close to the one called for by functional economy (or PSS). Among the many identified definitions, and in line with Stahel's work, we can quote Oksana Mont: *"PSS is the sale of the use of the product instead of the product itself"* (Mont, 2002). In this definition it is very explicit that the issue of commercial transactions is not the delivery of goods and/or services, but the production of use value for the customer. For example it can be illustrated by replacing the sale of a car by the sale of the use of a car (cat rental).

Considering that functional economy and eco-design both aim at satisfying customers' needs, their goals seem fully compatible. This presentation of the approaches may appear to be unconventional or even pretentious. Indeed, are these functional models the only ones to aim at promoting and satisfying customers' needs? Do other business models or design methodologies ignore these criteria? Has our industrial productive system developed for so many decades while ignoring the customer? This contemporary key approach would be a radical rupture in the way we consider the customer/supplier relationship. To avoid the pitfall of a caricatured and simplistic dichotomy, it is necessary to qualitatively define this shift from the provision of material goods to that of function and use. To understand the radicalism and the novelty of these approaches based on use value, it is necessary to explain two points in which they represent a rupture with more traditional approaches.

First, the causality is reversed between offers centred on use and the material supports of these offers. What these two approaches seem to bring are new links of subordination between this use value and the support offer that allows its realisation. The industrial logic initiates its approach on the offer. The offer drives the demand, which prescribes uses. The consequence of such a model is that the design process is controlled by the offer, and that the use values associated to this offer are not controlled by this offer mediation. In other words, the use values or useful production effect remain indirect, and are never the main and ontological goal of the approach. Functional economy and eco-design are precisely, because of their requirement of reasoning about functions, methodologies which call for the overthrow: from the determination of use values to the product.

Second, "customers' needs" are redesigned. Adopting a functional approach requires deconstructing the dominant view of need or user satisfaction on at least two points: (1) do not interrogate needs from the users' point of view but from the point of view of usage situations and (2) do not postulate pre-existing needs for such situations.

First of all, use value must be understood in relation with a user, and in given circumstances. It is frequently exposed that use value is a subjective value, intimately close to consumer needs and to utility as evaluated by this consumer. This subjective vision tends to "substantify" the use value, to enclose it in subjective individual stabilized preferences (Spread, 2011). It might be objected that beyond intrinsic user preferences, situations of use might be privileged to consider this concept of use value. For instance, let's consider the same user, a unique "substance", in two different situations related to the example of automobile. When renting a car, it is probable that for this user the use value of all-terrain vehicle will be greater for an excursion in a desert or in forest than for shopping in town. If we agree with this example, we must admit that we have to conceptualize the use value "in situation" more than "in personalization". This situated approach is close to the pragmatist approach as exposed by John Dewey. Following Dewey, we can define situations as integration processes of heterogeneous elements. As a consequence of this heterogeneity, situations must be considered as fundamentally singular, which means that customers' needs must be considered in the context of a singular problematic situation (Dewey, 1939). But we have to admit that both for functional economy and eco-design, the situated dimension of use value remains weakly integrated.

The second point relates to the deconstruction of the postulated pre-existence of needs. Answering a need would then suppose a previously defined expectation, before engaging a relationship or transaction with the solution provider. As a consequence, the customer would be a stable entity or substance, with determined expectations. Following this position, the capacity to produce outcomes or use values would depend on the ability for producers to access and to reveal these pre-existing needs and expectations. We can qualify this vision as a "fiction", as developed in the market pull approaches. On the contrary, and we assume this vision, the behavioural hypothesis is to postulate that user needs are initially undetermined, approximate, incomplete, because of the singular and problematic situation they are engaged in. Therefore, engaging in a functional economy or attempting to produce outcomes implies adopting an approach in which problems and solutions are not taken for granted but have to be co-defined and co-constructed (Brown, 2009). This process of problem co-construction and solution co-definition is at the core of the uses-centred and functional approaches. Refusing the position of pre-existing users' needs or unveiling expectations while considering the conception process as a collective construction process is a radical renewal of these approaches centred on uses, related to the most widespread ones (Brown, 2009). On this point, FA is not ambiguous. The need is there, pre-existing in the design process. The value analysis is addressed to a determined user. The user is determined by his explicit or implicit and existing or potential needs, ("Norme NF 1325-1," 1996). The aim is then to identify these more or less explicit, more or less hidden, but present needs. The definition of function is based on the answer to a user's need but more or less explicitly, supposed to be pre-existing or prescribed (Chandrasekaran, 2005; Erden et al., 2008). This conceptual characterization of user needs remains quite implicit in the functional economy approach. However, some contributions shed light on the shift of value creation from product to customer relationship. This means that firms now consider the opportunity to create new value throughout the customer relationship. Consequently, if this relationship can be considered as a source of value creation, it implies that this relationship allows the (positive) evolution of the customer situation. This cannot be separated from the co-production of use value between suppliers and customers. The initial customer indeterminacy, related to his expectations and needs, is progressively reduced through an interactive process that is at the core of value creation in this model.

Following this review of FA and FE in their normative dimension, it seems logical to conclude that these two approaches have a rather pronounced degree of similarity. They both aim to break away from a design logic initiated and directed by the offer. Their methodological approaches are anchored on use and service. The product's offer is subordinated to this primary goal. Despite some ambiguities, especially about eco-design, the approach centred on use seems to unify the two methods. Based on this common objective, a strong complementarity of these two approaches emerges: FA operating on the technical dimension and FE on the economic dimension. Thus, the joint utilisation of these two approaches would seem to be destined to cross-fertilization for the renewal of an offer to move towards the service, the use. Function is the center of the design or eco-design process and in functional economy to design new servicial business models centred on use. Through the focus on function, the different stakeholders find their interests. The designers use the function to answer standards and technological opportunities, the users find their use needs through the function, and finally, function allow to answer societal issues with answering to environmental standards, environmental technological opportunities through eco-design for example, and environmental psychological needs of users (environmental activits, eco-users) (Figure1).

But the second conclusion that can be made at this stage is precisely that this shift to a service or use centred approach does not seem to be considered in all its radicalism. This is particularly the case for eco-design. If it is to remain bound to the use or needs associated to a determined user, eco-design seems diverted from its promises to renovate the design model. The two approaches mostly differ on this conceptualisation of the needs. Yet the renewal of the conceptualization of needs remains quite implicit in functional economy too. A normative analysis may be not sufficient to evaluate if this differentiation is only superficial or more profound. That is why it seems necessary, at the end of this first part, to "pass the field test", to follow up on this comparison of the two methods and their respective scope for the renewal of productive models. Indeed, it seems that in most cases, the implementation of eco-design and functional economy is difficult (Ceschin, 2013; Eisenbart, Gericke, & Blessing, 2013).

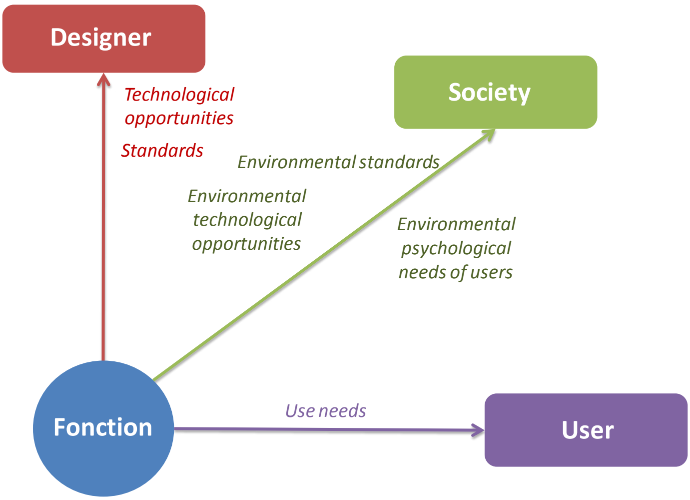

Figure 1: the contributions of function for different stakeholders of eco-design and functional economy

2.1. Operationalizing eco-design and functional economy

The second part of this paper is built on a more pragmatic analysis. It aims at studying the industrial operationalization, or in other words, the industrial integration of these two approaches. The real deployment of FA or FE methods in the industrial world often leads to results diverging from the main initial theoretical targets.

The study was conducted under two projects: the OCEF project financed by the ADEME and the IDCyclUM project financed by the ANR. It was conducted between June 2013 and January 2014, grouping several academic partners. It aimed at developing actionable insights to operationalize the concept of functional economy. Carrying out interviews with those involved in functional economy, supported by the analysis of classical cases (like Xerox and Michelin) allowed us testing our proposal in relationship to the common integration of the "function" in functional economy and eco-design.

The study was based on semi-conductive interviews with Business to Business (B to B) and Business to Consumer (B to C) companies. As the B to B market was the precursor market of functional economy, the B to C market shows signals of changes in consumption behaviour oriented toward functional economy. Interviews were carried out face-to-face, recorded when possible and conducted using an interview guide incorporating questions about the previously used elements (see part I): New use values, constructing the offer from use values point of view and co-producing use values. Since only four companies that were relevant with the approaches of functional economy and functional analysis have agreed to be interviewed, we decided to complete the study with more cases extracted from literature. These classical cases have been chosen by combining the more recent papers analysing cases of functional economy (Ceschin, 2013; Fromant, 2012; Renault, Wolfgang, & Dalsace, 2013). The data obtained was anonymised (for confidentiality matters) and transcribed in interview synthesis reports sent for validation to the interviewed parties involved. Four interviews were conducted, completed by the analysis of nine cases from the secondary literature.

As a result, although the literature defines gradual types of the implementation of functional economy and functional analysis (from material goods centred to services or functionality centred innovations), it seems that companies have difficulties in going beyond the first level of the two approaches. The realised monographs reveal that most of the cases belong to the product-based service and the "bundle" model concerning functional economy. In the same way, regarding eco-design, very few cases adopt a re-think typology of eco-design. In most eco-design cases, definition and characterization of function is limited to the definition of a functional unit.

The difficulties for companies to move toward the highest type of functional economy and/or eco-design can be explained by the necessity to rethink the productive organization, and rethink the added value (Boons & Ludeke-Freund, 2013; Boons, Montalvo, Quist, & Wagner, 2013). These new approaches, centred on functions in their conceptual form, require companies to adopt an approach driven by the uses and a co-constructed approach that is difficult to implement. Disruptive innovation seems too risky (Ceschin, 2013), leading to the adoption of less innovative functional economy or eco-design. Thus, as a graduation exists in eco-design types and functional economy types, a graduation has been revealed in the establishment by use values and the production guided by use values. These gradual models act as intermediary objects (Boujut & Blanco, 2003) in transition toward more functional approaches, or as differentiation objects on the market.

This study has allowed a complementarity between FA and FE to be demonstrated. If functional economy in its ideal form seems focused on the sale of use values without having a systematic environmental interest, eco-design is on the contrary strongly anchored on material good but with an environmental goal. The association of these two “practices” in the construction of sustainable innovation thus seems promising. As the different cases reveal, most of the companies associate functional economy and eco-design to adapt their products to a business model centred on use and function. The functional unit acts as a reference in their business model in order to operate the move from material good sale to function sale. According to these results, functional economy seems more linked to the integration of functions and uses than eco-design from a pragmatic point of view. But functional economy uses eco-design as a tool to achieve this goal of a functional business model which is uses-centred.

3. Conclusion

This article provides a comparison of FA (products design) and FE (design of servicial business models) based on their integration of the use concept through the function. Our research question was: *what are the similarities and differences between FA and FE in terms of use and functionality?* In that way, the two approaches have been compared on both a normative level and a pragmatic level.

From a conceptual aspect, both approaches defend the value of an offer as inseparable and associated to the uses delivered to the user. Besides, both approaches tend to contribute to sustainable development issues through this attention to uses.

Nevertheless these two approaches present some differences as FA is a design method, restricted to product design, and FE adopts a more inclusive target.

From the pragmatic point of view, practical cases show a strong anchoring on material goods as opposed to literature’s definitions. This finding seems to be in conflict with the focus on use. This can be explained by the radicality involved in the moving from a material goods-centred approach to an approach centred on the uses. Companies tend to adopt a progressive trajectory, which impairs the initial concept. Nevertheless, it seems that the two approaches are complementary: functional economy uses functional analysis as a tool to achieve the goal of a functional business model, centred on uses.

In our approach it would have been interesting to interview and compare more companies to increase the relevance of the results. Nevertheless, companies that have implemented functional economy voluntarily are still few, and there are little experience feedbacks. Then, regarding our suggestion about an association of FA and functional FE to reach the goals of sustainable development, it seems difficult to measure the environmental potential of functional economy unlike eco-design.

As a conclusion, we suggest that the concept of use is a common target of functional analysis and functional economy. But it seems really difficult for companies to implement it in its purest form. Thus, it could be interesting to develop research on methods and models to facilitate the implementation of such models centred on uses as functional economy and functional analysis or eco-design in companies.

4. References

[AFNOR 1996], Norme NF 1325-1. 1996.

[AFNOR 2006], Norme ISO 14040. 2006.

[Boons & Ludeke-Freund 2013] ,Boons, F., & Ludeke-Freund, F. (2013). Business models for sustainable innovation: state of the art and steps toward a research agenda. *Journal of Cleaner Production, (45), 9–19.*

[Bonns et al. 2013], Boons, F., Montalvo, C., Quist, J., & Wagner, M. (2013). Sustainable innovation, business models and economic performance: an overview. *Journal of Cleaner Production, (45), 1–8.*

[Boujut & Blanco 2003], Boujut, J. F., & Blanco, E. (2003). Intermediary Objects as a Means to Foster Co-operation in Engineering Design. *Computer Supported Cooperative Work, 12, 205–219.*

[Brown 2009], Brown, T. (2009). Change by Design (*Collins Business*).

[Ceschin 2013], Ceschin, F. (2013). Critical factors for implementing and diffusing sustainable product-Service-systems: insights from innovation studies and comanies' experiences. *Journal of Cleaner Production, (45), 74–88.*

[Chandrasekaran 2005], Chandrasekaran, B. (2005). Representing function: Relating functional representation and functional modeling research streams. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 19, 65–74.*

[Chen & Chuang 2008], Chen, C. C., & Chuang, M. C. (2008). Integrating the Kano model into a robust design approach to enhance customer satisfaction with product design. *International Journal of Production Economics, 114, 667–681.*

[Dewey 1939], Dewey, J. (1939). Logic: The Theory of Inquiry. *BINDER.*

[Eisenbart et al. 2013], Eisenbart, B., Gericke, K., & Blessing, L. (2013). An analysis of functional Modelling approaches across disciplines. *In Design Theory and Research Methodology (Vol. 2, pp. 163–172). Seoul, Korea: Udo Lindemann, Srinivasan V, Yong Se Kim, Sang Won Lee, John Clarkson, Gaetano Cascini.*

[Erden et al. 2008], , Erden, M., S., Komoto, H., Ban Beek, T., J., D'Amelio, V., Echavarria, E., & Tomiyama, T. (2008). A review of function modeling: Approaches and applications. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing,* *22, 147–169.*

[Fromant 2012], Fromant, E. (2012). Les clés du renouveau grâce à la crise! Economie de fonctionnalité: Mode d'emploi pour les dirigeants d'entreprise (*EMS*).

[Matzler & Hinterhuber 1998], Matzler, K., & Hinterhuber, H. H. (1998). How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function deployment. *Technovation, 18(1), 25–38.*

[Mont 2002], Mont, O. (2002). Clarifying the concept of PSS. *Journal of Cleaner Production, 10, 237–245.*

[Pahl et al. 2007], Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. H. (2007). Engineering Design A System Approach (*Springer Science and Business Media*).

[Renault et al. 2013], Renault, C., Wolfgang, U., & Dalsace, F. (2013). Business Model Innovations: Michelin Fleet Solutions_From *selling tires to selling kilometers (p. 5). Paris.*

[Spread 2011], , Spread, P. (2011). Situation as determinant of selection and valuation. *Cambridge Journal of Economics, 35(2), 335–356.*

[Xu et al. 2009], Xu, Q., Jiao, R. J., Yang, X., & Helander, M. (2009). An analytical Kano model for customer need analysis. *Design Studies, 30, 87–110.*

Functions, Value Criteria and Usage

Methods in Value Management, Innovation Marketing and Strategic Management

Jean-Claude BOLDRINI

Université de Nantes - IEMN-IAE

1. Introduction

Designers are familiar with the concepts of Value, Function and Usage. Eco-design requires the environment to be taken into consideration for these concepts. This paper investigates the links, in (eco)design, between Value, Function and Usage. The communication is based on three assumptions. First, the environmental criteria are, as aesthetic or economic criteria, attributes of the value of a product or a service. Second, the environmental criteria can be or should be parts of functional requirements. Third, the environmental criteria may contribute to the quality of usage or to the usability of products.

Three major themes concerning Value, in business and engineering, will be tackled: value analysis (how do customers analyze value?), value creation (how can firms produce value in a market-oriented product development?) and value delivery (who are the actors that create value, and what delivery process provides the best value for what sorts of customers?) [Lindgreen et al., 2012].

In the paper, we will first define the polysemous words "Value", "Function" and "Usage" used in a wide range of subjects (design, management…). We will then detail the definition of Value in the European Standard EN 12973(2000) and see its benefit. Finally we will propose a model for sustainable value orchestration.

2. Value, a Multidimensional and Unsteady Construct

Since Plato, Aristotle or Epicurus an abundant literature has been devoted to Value in various fields such as philosophy, economics, psychology, sociology, marketing, industrial design or behavioral sciences (for an overview, see [Ueda and al., 2009]). Since the 1950s' four main periods have been observed in the value research: 1) investigating into human values, 2) connecting human values with the use of products or services, 3) considering the trade-off between giving and taking (adopting the price/sacrifice concept) and 4) focusing on Value as experience [Park & Han, 2013].

In order to capture recent definitions of the concept of Value in the field of business, we have checked how this word is defined in best-selling books, in English publications as well as in French ones: *Blue Ocean Strategy* [Kim & Mauborgne, 2005], *Marketing* [Kotler & Armstrong, 2010], *Business Model Generation* [Osterwalder & Pigneur, 2010] or *Innovation Marketing* [Le Nagard-Assayag & Manceau, 2011]. Surprisingly, it must be noted, after referring to the indexes of these books that the concept of Value is most of the time only superficially alluded to.

More consistent knowledge is provided in academic papers but we will only discuss four points. First of all: being a producer or a user generally influences the perception of what Value is. When the customers want to maximize the perceived benefits and minimize the perceived sacrifices (money, time, effort) (Lindgreen and al., 2012), the suppliers try to capture value under three forms (financial payment, technological knowledge and reputation of doing business with leading-edge firms) [Smals & Smits, 2012]. Second, there is often a conflict between the values of individuals (the pursuit of pleasure or happiness) and the values of a whole society (sustainability within ecological, social and economic contexts) [Ueda and al., 2009]. Third, a distinction can be operated between product/service value, life value and user value [Park and Han, 2013]. Product/service value is attached by users to a product or service and can be defined as "subjective preference for and evaluation of a product or service that facilitates achieving the user's life value". Life value is defined as "desirable states of existence [happiness, freedom…] or modes of behavior". "User value is the value that is satisfied when a user interacts with a product or service" (by purchasing or using it). User value can be regarded as a subset of life value [Park & Han, 2013]. Figure 1 shows the relationship between life, user and product/service value. Fourth, if money is an important criterion of Value, numerous forms of values are non-monetary: reputation, trust, commitment, reliability of a product or a business partner, innovativeness of a supplier… [Smals & Smits, 2012; Lindgreen and al., 2012].

Most of the time researchers only focus on narrow aspects of Value (purchasing behavior for marketers, exchange value for economists, product value for engineers). This prevents them from having a comprehensive understanding of how value could be analyzed, delivered or co-created.

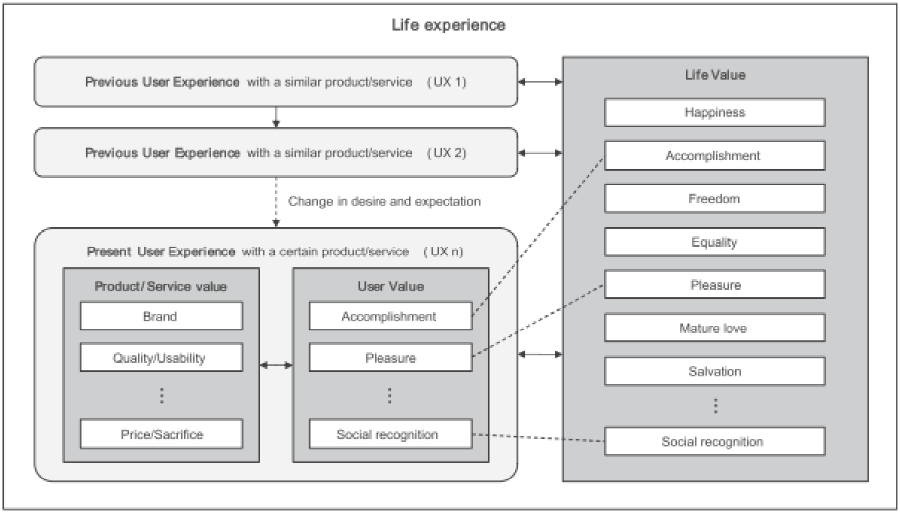

Figure 1: Value concept: Life, user and product/service value [Park & Han, 2013]

3. Function and Usage in Value Analysis

Value analysis is, according to the European Standard EN 1325-1 (1996), "an organized and creative approach using a functional and economic design process which aims at increasing the value". Functional analysis is the process to increase value. It consists in providing a complete description of the final purpose of a product or service during all the phases of its life cycle. An important step of functional analysis is to completely describe the functions that is to say the "effect expected of a product, or performed by it, in order to meet a part of the need of a definite user" (EN 1325-1). Figure 2 is an example of function descriptions for an offshore wind turbine.

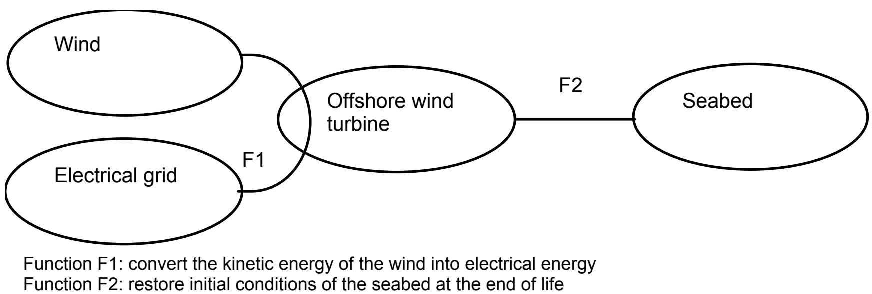

Figure 2: Two possible function descriptions for an offshore windturbine

Since the publication of the European Standard EN 12973, in 2000, Value is defined as "the relationship between the contribution of the function to the satisfaction of the need and the resources used in achieving that satisfaction". This definition offers a basis for a detailed characterization of Value [Boldrini, 2001] (figure 3).

	Satisfaction of need: - functional, - social, - affective, - aesthetic, - hedonistic, - environmental - epistemic, - ethic and spiritual, - …
Value a	――――――――――――――――
	Use of resources: - monetary, - time, - energies, raw material, - equipment, - human energy, psychological costs, - building, natural areas, - …

Figure 3: A detailed characterization of value [Boldrini, 2001]

With this perspective, it is no longer necessary to comment carefully the notion of Usage. It may simply be considered as a specific combination of functions, with corresponding value criteria, during the use phase of the life cycle of a product.

This value characterization proposed in figure 3 also meets the request of authors who appeal for an integration of multiple conceptions of values (ecological, pragmatic, economic, psychological…) as they consider that Value is realized through interaction among consumers, products, and producers in a society [Ueda and al., 2009].

4. To a Sustainable Value Orchestration

To maximize product/service performance during the entire life cycle of a product, it is no longer possible to consider that companies are the only provider of Value through the offer of goods or services to the customers. We should better consider that Value is co-created by the interaction of artifacts and all the parties present along the Value chain [Lindgreen and al., 2012]. With this perspective, the "realm of value" [Ueda and al., 2009] cannot be limited to the product/service itself (the efficiency of the engine in an electric car for example). It must encompass the product/service, its whole environment and all stakeholders (for example, an innovative system of transportation with services adapted in order to limit congestion, pollution and road insecurity in urban environments). So the actors and the social systems have to innovate not only in new goods, new methods, new markets, new sources of raw materials or new organizations, as in Schumpeter's theory of Economic Development, but also in the dynamic interaction among social, natural and artificial systems to achieve sustainable value [Ueda and al., 2009]. However research hasn't yet proposed robust models for that "sustainable value orchestration" [Lindgreen and al., 2012].

5. References

[Boldrini, 2001] Boldrini, J.-C., 2001. « La conception à objectifs désignés : vers un modèle intégrateur », *Research master dissertation*, University of Nantes

[Kim and Mauborgne, 2005] Kim, W. C. and Mauborgne, R., 2005. *Blue ocean strategy. How to create uncontested market space and make the competition irrelevant*, Boston (Mass.) Harvard business School press cop.

[Kotler & Armstrong, 2011] Kotler, P. ; Armstrong, G., 2011. M*arketing : an introduction*, Upper Saddle River (N.J.), NJ Pearson cop. (10th ed.)

[Le Nagard-Assayag & Manceau, 2011] Le Nagard-Assayag, E. ; Manceau, D., 2011. *Le marketing de l'innovation. De la création au lancement de nouveaux produits*, Paris, Dunod (2e éd.)

[Lindgreen and al., 2012] Lindgreen, A. ; Hingley, M. K. ; Gant, D. B. ; Morgan, R. E., 2012. "Value in business and industrial marketing : Past, present and future", *Industrial Marketing Management*, 41, 1, 207-214

[Osterwalder & Pigneur, 2010] Osterwalder, A. ; Pigneur, Y., 2010. *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*, Hoboken (NJ), John Wiley & sons, inc

[Park & Han, 2013] Park, J. ; Han, S.H., 2013. "Defining user value : A case study of a smartphone", *International Journal of Industrials Ergonomics*, 43, 274-282

[Smals & Smits, 2012] Smals, R.G.M. ; Smits, A.A.J., 2012. "Value for value - The dynamics of supplier in collaborative new product development", *Industrial Marketing Management*, 41, 1, 156-165

[Ueda and al., 2009] Ueda, K. ; Takenaka, T. ; Vancza, J. ; Monostori, L. 2009. "Value creation and decision-making in sustainable society", *CIRP Annals - Manufacturing Technology*, 58, 681-700

Fuon theory: beyond comparing oranges with oranges

Daniel COLLADO-RUIZ[1,], Hesamedin, OSTAD-AHMAD-GHORABI[2]

[1] Universidad Politécnica de Valencia, Integration of Design & Environmental Assessment, Department of Engineering Projects

[2] Ferchau Engineering GmbH, Germany

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

2. 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.

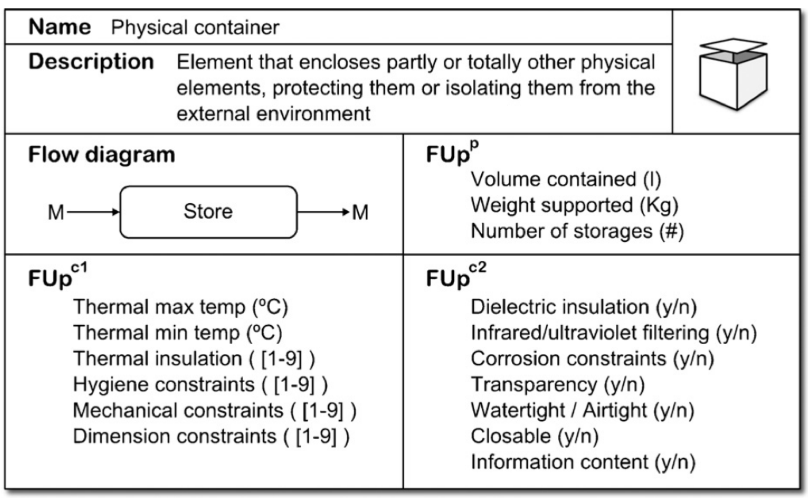

Figure 1: Container Fuon, from Collado-Ruiz and Ostad-Ahmad-Ghorabi 2010b

- 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.

3. 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.

4. 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.

5. 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-intensive 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.

6. References

[Collado-Ruiz, D., Ostad-Ahmad-Ghorabi, H., 2010a] Collado-Ruiz, D., Ostad-Ahmad-Ghorabi, H., 2010a, Comparing LCA Results out of Competing Products – Developing Reference Ranges from a Product Family Approach. Journal of Cleaner Production 2010, 18 (4): 355-364.

[Collado-Ruiz, D., Ostad-Ahmad-Ghorabi, H., 2010b] Collado Ruiz, D., Ostad Ahmad Ghorabi, H. 2010b, Fuon Theory: Standardizing Functional Units for Product Design. Resources, Conservation and Recycling, 2010, 54: 683 691.

[Ostad-Ahmad-Ghorabi, H., 2010] Ostad-Ahmad-Ghorabi, H., 2010, Parametric Ecodesign – Parametric Ecodesign – Development of a Framework for the Integration of Life Cycle Assessment into Computer Aided Design. Suedwestdeutscher Verlag fuer Hochschulschriften, 2010, ISBN: 978-964-2940-29-5

[Ostad-Ahmad-Ghorabi, H. et al. 2013] Ostad-Ahmad-Ghorabi, H., Schäfer, T., Spielauer, A., Aschinger, G., Collado-Ruiz, D., 2013, Development of the Digital Storage Fuon. Proceedings of the 19th International Conference on Engineering Design (ICED13), Design for Harmonies. 2013 (2): 133-142. ISBN: 978-1-904670-45-2.

[ISO, 2006] ISO, 2006, 14044: environmental management-life cycle assessment-requirements and guidelines. International Organization for Standardization.

Function, economic actors and life cycle

Anne VENTURA

Université de Nantes, laboratoire GeM, chaire génie civil éco-construction

1. Introduction

The purpose of the presentation is to provide an overview of function design over the life cycle of a product, showing that it is connected to various actors in the life cycle. It is more a general set of thoughts and questions than a research result. The function is taken from its general definition found in the dictionary: "the role of an element in an ensemble". From this definition, it appears that both roles and ensemble have to be defined when characterizing a function and that they all vary according to the life cycle step considered: production, usage and end of life stages.

2. Production stage

At the production stage, the designer is expected to provide a product with functionalities responding to a given customer that wills to pay for it. A distinction can be made between functions directly offered to the user of a product, that can be called "internal functions" and functions that are offered to a larger part of the society, and not only to the user itself. These can be called external functions; they correspond to a larger ensemble in which the role is played. External functions can be depolluting or aesthetical functions of a building for instance. All functions are however linked to a stake to which the product is expected to bring a solution or an answer. At this stage, functions are expected functions, or "potential functions" because they are characterized and set previously to usage. Furthermore, in the case of a complex product system such as a building, functions are numerous, and there are nested scales (Ventura et al., 2012) inside which combination of functions of elementary products will contribute to the function of the assembled device at the upper scale (see Fig. 1).

3. Service life stage

At the service life phase, functions defined previously at production stage will be confronted to usage situations, and can prove having various behaviors: (i) independant when not varying with context of usage and surrounding conditions nor with time; (ii) constant when depending on the context of usage but not varying with time, and (iii) dynamic when varying both with surrounding conditions and time. Furthermore, user's behaviors should be better modeled to notably understand the reasons they might want to maintain, replace, or still use a product with altered functions. This is both linked to implicit functional priorities that should be revealed (including the feeling of obsolescence), as well as to economic concerns. These aspects should be better modeled at the design phase to include both expectations from users as well as technological context of usage.

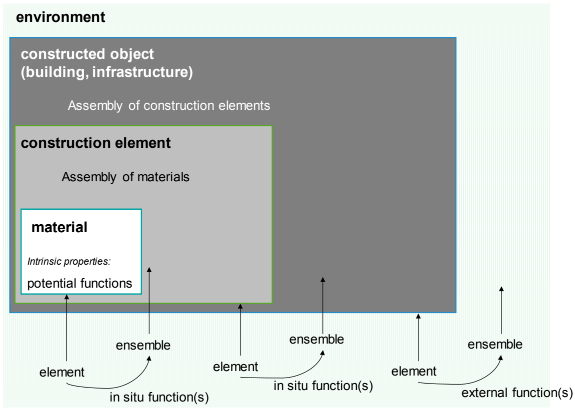

Figure 1: In situ and external functions inside nested scales for a building

4. End of life stage

The end of life is almost never accounted in the design phase of a product, unless it is required by legal obligations. However, according to EU regulation (EU 2008), the status of waste can be ended when a list of conditions is fulfilled, including that the future product can fulfill desired functions in a market. In an eco-design perspective, this would require an "end-of-life designer" able to model influence of a further product on the target market.

5. Conclusion

Functionality is often reduced to technical initial properties of products. However, according to user's behavior, to context of usage and end-of-life favorable conditions to further reuse or recycling, more complete models should be developed and used at initial design stage for better environmental performances of products.

6. References

[Ventura et al. 2012] Ventura, A., Rachida, I., Van Schoors, L., Andrianandraina, A., Van Der Werf, H., others, 2012. How to use LCA to assess materials as eco-design parameters in construction projects? *In: Proceedings Rilem PRO86. Presented at the International Symposium on Life Cycle Assessment and Construction, Ventura and de la Roche, Nantes, France, pp. 89–96.*

[EU 2008] European directive EU 2008/98/EC

Quantification of utilities of products in usage situations

Bernard YANNOU

Laboratoire Génie Industriel, CentraleSupélec, Université Paris-Saclay

1. Abstract

The presentation aims at giving a literature review concerning innovative design and various definitions and methods.

More than 18 methods were identified in a literature review on functional modeling (Erden et al. 2008). They lead to a consensus that function is a term with a number of co-existing meanings and with the common role of relating goal descriptions of devices with structural descriptions of the devices in a general interdisciplinary way (Vermaas and Eckert 2013). Functions are thus used to express expected actions or expected effects (which are different) contributing to the goal. However, goals are generally not well defined in classical design and functional analysis. Functions are elementary actions contributing to larger goals, and goals are those that should be investigated previously to functional properties. Indeed, goals will depend on usage situations, i.e. users might have unexpected behaviors, and they should be defined in order to solve problems or so-called "pains" encountered by users. Furthermore, it appears important to measure the satisfaction of users. The classical "how-why" method is not sufficient because it does not consider affordances. Affordances are behaviors or needs that can be afforded once something exists (Maier and Fadel 2003). There are existing methods taking affordances into to account all along the design process (Cormier et al. 2013). The example of a fridge shows that functional analysis alone only partially covers needs expressed with affordances.

Design for market is an approach that mixes techniques for quantitative marketing with design exploration of configurable products (Papalambros 2013). This design model includes features of the product, its price, as well as its volume of production. This enables to define a cost model, and further a market demand model. The success of the product can be simulated as well as the resulting profit margin. These models compare desirability in terms of product's properties or attributes, price and environmental properties. Such a model is detailed on the case of a hybrid car in (He et al. 2012). To model market demand, several methods

exist such as utility function, fuzzy rules or multi-criteria decision methods. Only utility function is detailed in the presentation as the most common method.

Usage modeling is also needed to design products or product families adapted to cover the variety of user needs in different usage situations. Three frameworks of design optimization are considered by Yannou et al. (2013). First, the conventional approach of designers is to express optimization objectives as a set of targeted performance levels of a product. The main drawback of it is that this target specification vector represents an "average" need of a wide and diverse population. The second classical approach is to build a market share model by asking to sampled people who are representative of targeted market segments to fill surveys on how the product is appreciated through its apparent attributes. From the survey analysis a choice model is determined with conjoint analysis or discrete choice analysis techniques. However, this method only applies to existing products, but not to innovative products. Secondly, people are, most of time, asked to provide a global assessment of the products; i.e. their assessments do not depend on product adequacy to possible usage situations. So a third "design by usage simulation framework" has been proposed by Yannou et al. (2013). A "usage scenario space" is defined. It is a collection of usage scenarios informing how people behave and may generate different product or service performances in different usage situations. This requires socio-demographic data for customers as well as descriptions of conditions in which product can be used, and expectations in terms of product's performances.

Physics-based models of the product behavior and customer's behaviorial models – often fitted after human appraisal experiments – may be used as long as they may be modelled. An example of the sizing of a Bosch jigsaw family is illustrated in (Wang et al. 2013). Following a series of user performance simulations under all the usage scenarios, the product ability to cover satisfactorily – with a good degree of performance – the whole set of inventoried usage situations is characterized by so-called "usage coverage indicators". These indicators may allow comparing a product concept with existing competing products in terms of its ability to cover, in a dominant way, a sufficient subset of usage situations.

When such physics and ergonomics based models do not exist, learning technique such as Bayesian networks approaches may be used to link usage scenario pieces to performance and satisfaction vectors. This is the case of the modeling of the usage scenario space of fall situations for the elderly (Bekhradi et al. 2015). In this paper, the global effectiveness of some apparatus to prevent and detect elderly falls is simulated over the multiple fall situations defined in the usage scenario space. In addition, scripts for innovative efficient systems are tested to better cover orphan usage situations – with no efficient/effective solution on the market for covering these painful situations.

As a conclusion, here are some messages:

- Functional approaches are not enough and often ambiguous for modelling a diversity of user performance expectations in different situations,
- Design for market approaches already exist but are often not linked with service effectiveness and efficiency in different users' situations.

Thus, "design by usage" approaches must be used more intensively. They require physics and ergonomics based models or learning techniques to link a segmentation of usage situations to varying service performances and effectiveness. This is the price to pay to be able to design products and product families better adapted to customized situations of user needs.

2. References

[Bekhradi et al. 2015], Bekhradi A., Yannou B., Farel R., Zimmer B., Chandra J., 2015. Usefulness Simulation of Design Concepts, *Journal of Mechanical Design*, 137(7) - special issue on "User Needs and Preferences in Design Engineering", pp. 071414-071414-12, doi: 10.1115/1.4030180

[Cormier et al. 2013], Cormier P., Olewnik A. and Lewis K., 2013. Towards a formalization of affordance modeling in the early stages of design, *IDETC conferences*, Chicago.

[Erden 2008], Erden M.S., Komoto H., Van Beek T.J., D'Amelio V., Echavarria E., Tomiyama T., 2008. A review of function modelling: Approaches and applications. *AI-EDAM*, 22, 147-169.

[He et al. 2012], He L., Chen W., Hoyle C., Yannou B., 2012. Choice modeling for usage context-based design. *Journal of Mechanical Design*, 134 (3).

[Maier and Fadel 2003], Maier J., Fadel G., 2003. Affordance-based methods for design, *IDETC conferences*, Chicago

[Papalambros, 2013], Papalambros P., 2013. Design for market, Keynote Presentation, *ICED 2013*, Seoul, August 2013.

[Vermaas and Eckert 2013], Vermaas P., Eckert C., 2013. *Special issue on "Functional descriptions in engineering". AI-EDAM*, 27 (3).

[Wang et al. 2013], Wang J., Yannou B., Alizon F., Yvars P.-A., 2013. A Usage Coverage-Based Approach for Assessing Product Family Design. *Engineering with computers*, 29 (4), 449-465.

[Yannou et al. 2013], Yannou B., Yvars P.-A., Hoyle C., Chen W., (2013), Set-based design by simulation of usage scenario coverage. *Journal of Engineering Design*, 24(8), p. 575-603, doi. 10.1080/09544828.2013.780201.

Systemic approach of collective biogas plants

To define relevant functions for their environmental assessment

Faustine LAURENT[1, 2, 3], Thierry BIOTEAU[1, 3], Lynda AISSANI[1, 3], Guillaume ACCARION[2], Fabrice BELINE[1, 3]

[1] IRSTEA, UR GERE

[2] AKAJOULE

[3] UEB

1. Introduction

Anaerobic digestion is a natural process by which organic material is broken down by micro-organisms in anaerobic conditions. This process is used to manage waste from agriculture, industries or municipalities and to produce at the same time a biogas that can be converted into energy (electricity, heat, injection into the gas grid or transport fuel) and a digestate that can be used as a fertilizer.

The deployment of anaerobic digestion units has been supported in France by public authorities those past few years, as it could help meet the European "three 20 target" related to energy and climate issues [MEDDE, 2011]. Energetic and economic considerations are drivers for developing centralized plants rather than distributed plants [Solagro, 2014]. But structuring such collective units is complicated because: (*i*) collaboration of many stakeholders with various expectations is required, (*ii*) opportunities for biogas schemes are highly site-dependent (waste quantities and properties, outlets for the biogas recovery and the spreading of digestate) and (*iii*) there is a lack of dedicated tools for modeling collective anaerobic digestion units and assessing their environmental balance.

In fact, any biogas plant will cause positive and negative impacts to the environment, the key issues being resource depletion, global warming, acidification and eutrophication [Giard et al., 2014]. Regarding global warming potential, for example, every stage of the anaerobic digestion process is responsible for both GHG emissions and savings [Rehl et al., 2013]. Since the deployment of biogas systems is connected to environmental concerns, the overall impact of any planned unit should be appraised. For this purpose, Life Cycle Assessment (LCA) stands as the pre-eminent tool for assessing environmental impacts caused by biogas systems at all stage of their life cycle [Giard et al., 2014].

But when it comes to biogas systems, the LCA practitioner will face methodological issues due to the fact that the anaerobic digestion process fulfils several functions: it is an option for handling organic residues, which origins are varied (manure, waste from agri-food industry, municipal solid waste, etc.), it is a source of renewable energy by way of biogas conversion and it is a solution for concentrating the nutrients of the digestate in order to improve its fertilizing efficiency. One should bear in mind that the main function, as for the potential scenarios for biogas systems, arises from local opportunities and constraints. These biogas systems typical issues are in agreement with three of the LCA problems during the phases of Goal and scope definition and Life cycle inventory identified by Reap et al.: (*i*) functional unit definition, (*ii*) alternative scenario consideration and (*iii*) local technique uniqueness [Reap et al., 2008].

The aim of this study is to develop a conceptual framework involving spatial factors during the functional definition of a projected biogas plant within a territory. A systemic approach of anaerobic digestion implementation options was conducted thanks to Geographic Information Systems (GIS) and led to the definition of several indicators: four major indicators expressing the potential functions that the system could provide and twelve secondary indicators for scenario consideration. The indicators results analysis and comparison thanks to a decision matrix will help define a relevant functional unit and consider scenarios suitable with the local opportunities and constraints. This work is a previous step for the environmental impact assessment by way of LCA. The feasibility of such a conceptual framework was tested on two contrasting territories.

2. Material and Methods

The opportunities for deploying anaerobic digestion units within a territory depend on the local conditions regarding several sectors of activity. The systemic approach of both territories of study was based on spatial analysis of agricultural practices, energy demand and waste management and on consideration of natural and regulatory constraints.

FUNCTION	EXAMPLE OF FUNCTIONAL UNIT	CORRESPONDING INDICATOR
Waste management	"the treatment of 275,900 tons/yr of municipal source-segregated food waste" [Patterson et al., 2011]	WM
Energy production	"1 MJ of net energy delivered (electricity or heat)" [Blengini et al., 2011]	REn
Fertilizer production	"to process 1 ton untreated liquid manure into a mineral concentrate" [De Vries et al., 2012]	Nmin
Nutrient export	"1 kg nitrate that was actually exported or used in a non-agricultural way" [Rehl et al., 2007]	Nutr

Table 1: Major functions assigned to biogas systems in literature

Four major indicators were developed, corresponding to the four major functions provided by a biogas system, with compliance to the literature [Giard et al., 2014]: waste management (WM), energy production (REn), fertilizer production (N_{min}), nutrient export (Nutr) (see Tab. 1). Twelve secondary indicators reflecting local specificities were also developed but are not presented here.

SCORE	WMA[a]	REN[b]	NMIN[c]	NUTR[d]
5	> 5,000,000	<5%	>65%	>170 (>100)
4	5,000,000	5%	65%	170 (100)
3	3,500,000	9%	59%	162.5 (90)
2	2,000,000	13%	53%	155 (80)
1	500,000	16%	46%	147.5 (70)
0	100%	20%	40%	140 (60)
-1	125%	35%	34%	132.5 (50)
-2	150%	50%	28%	125 (40)
-3	175%	65%	21%	117.5 (30)
-4	200%	80%	15%	110 (20)
-5	>200%	>80%	<15%	<110 (<20)

[a] *from -5 to 0: quantities of MSW produced (tons/yr) / capacity of the local treatment plant (tons/yr); from 1 to 5: tkm (tons of MSW produced * transportation distance in km)*

[b] *% of renewables in the total energy consumption of the territory*

[c] *average input of mineral fertilizer (kg N_{min}/yr) / total amount of nitrogen required (kg N_{tot}/yr)*

[d] *kg of N_{org} (P_2O_{5org})/ha of arable land.*

Table 2: Score equivalence of the function indicators

The results of the function indicators should reflect the situation of the territory considered regarding each of the potential services that an anaerobic digestion system could provide. Every indicator is expressed as a single-score on a common scale ranging from -5 to +5, where +5 indicates that the function is crucial on the territory and -5 indicates that the function is no priority.

WM is based on the local practices for handling municipal solid waste (MSW): if a treatment plant sites within the territory, the score is between -5 and 0 and depends on the ratio between the quantities of MSW produced and the treatment capacity of the plant; if not, the score ranges from 0 to 5 and is proportional to the quantity of MSW produced and the transportation distances between the territory and the actual treatment plant (see Tab. 2). The higher the indicator's score, the stronger a local treatment option is required.

REn expresses the proportion of renewable energy produced compared to the national objective for 2020 (see Tab. 2). If the indicator's score is high, solutions for producing more renewables should be deployed, while a low score implies competition between renewable energy sources – especially concerning the electric grid capacity.

N_{min} is calculated as the ratio between the average inputs of mineral fertilizer and the total amount of nitrogen required on crops within the territory: if the indicator's score is high, the production of a fertilizer from organic substrate is locally a major issue (see Tab. 2).

Nutr is an indicator of the nutrient pressure within the territory, calculated as the ratio between the quantity of nitrogen and phosphorus from livestock manure and the total surface of arable land available for land spreading. When the ratio exceeds a regulatory limitation, exporting the surplus nutrient is of major importance. The higher score of nitrogen pressure and phosphorus pressure is assigned to Nutr so as to consider the worst case situation (see Table 2).

3. Results

The indicators' scores for the two territories studied (Terr1 and Terr2) are presented in Fig.1. These results show that expectations with respect to the services that a biogas plant can provide differ from a territory to another. Within Terr1, the handling of MSW and the production of renewables are crucial issues, while none of the four functions appears to prevail over the others for Terr2. Except for Nutr which has a negative score on Terr1 (meaning that livestock farming activity is marginal), all scores are above 2, which stands for opportunities in favor of biogas units deployment.

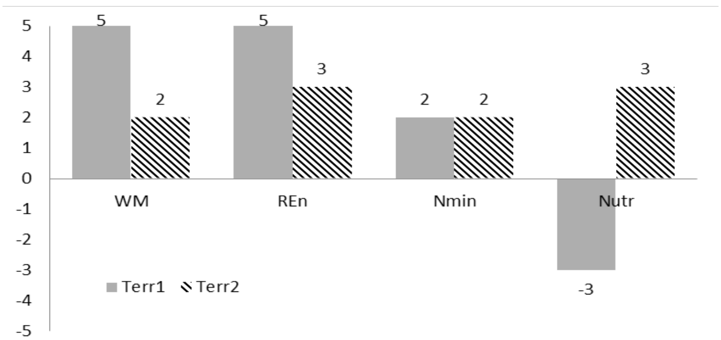

Figure 1: Function indicators' scores on both territories of study (Terr1 & Terr2)

The next step is to design anaerobic digestion scenarios in agreement with the requirements that were brought out. First, a prioritization has to be made between functions having the same indicator score, and the incompatibilities between several options must be identified. For example, the option for exportation of the surplus nutrient implies that the digestate is post-treated thanks to a process that will use a large amount of the energy recovered from the biogas, which mitigates the capacity for producing a renewable energy.

4. Conclusion & Perspectives

The spatial analysis conducted on two contrasting territories revealed that the services provided by a biogas system are connected to local particularities, and brings out the relevance of a site-dependent scenarios definition.

For this purpose, the construction of a decision matrix is in progress, involving results of function and secondary indicators, in order to formalize the scenarios definition (waste selected as inputs, sizing of the digester, options for biogas and digestate recovery, etc.), prior to LCA

5. References

[Blengini et al., 2011], Blengini G.A., Brizio E., Cibrario M., Genon G., 2011. "LCA of bioenergy chains in Piedmont (Italy): A case study to support public decision makers towards sustainability". *Resour. Conserv. Recycl.* 57, 36-47.

[De Vries et al., 2012], De Vries J.W., Groenestein C.M., De Boer I.J.M., 2012. «Environmental consequences of processing manure to produce mineral fertilizer and bio-energy». *J. Environ. Manage.* 102, 173-183.

[Giard et al., 2014], Giard L., Déchaux C., Laurent F., Aissani L., 2014. «Environmental assessment of biogas systems: A review of LCA case studies» (*forthcoming*)

[MEDDE, 2011], Renforcement du soutien à la méthanisation, Minsitère de l'écologie, du développement durable et de l'énergie : http://www.developpement-durable.gouv.fr/Renforcement-du-soutien-a-la

[Patterson et al., 2011], Patterson T., Esteves S., Dinsdale R., Guwy A., 2011. «Life cycle assessment of biogas infrastructure options on a regional scale». *Bioresour. Technol.* 102, 7313-7323.

[Reap et al., 2008], Reap J., Roman F., Duncan S., Bras B., 2008. "A survey of unresolved problems in life cycle assessment – Part 1: goal and scope and inventory analysis". *Int J Life Cycle Assess.*13, 290-300.

[Rehl et al., 2007], Rehl T., Doluschitz R., Jungbluth T., Müller J., 2007. "Environmental impact of different types of effluent processing" (conference paper), *VDI Berichte*, Vol. 2007, 323-333.

[Rehl et al., 2013], Rehl T., Müller J., 2013. «CO_2 abatement costs of greenhouse gas (GHG) mitigation by different biogas conversion pathways". *J. Environ. Manage.* 114, 13-25.

[Solagro, 2014], Solagro, 2014. «Expertise de la rentabilité des installations de méthanisation - Recommandations» (*forthcoming)*

The EcoCSP approach to negotiate functional specifications from preliminary design stage

Nicolas TCHERTCHIAN[1], Dominique MILLET[1], Pierre-Alain YVARS[2]

[1] Supmeca, USTV, Avenue de l'université, 83957 La Garde, France

[2] Supmeca, 3, rue Fernand Hainaut, 93407 Saint-Ouen, France

1. Introduction

Industrial growth has affected the conditions of life on earth as witnessed by the increase in ecological problems. In response to this situation, the concept of sustainable development has gradually emerged. Sustainable design is different from Eco design and Design for Environment because it goes beyond the environmental optimization [van Weenen 1995]: it attempts to incorporate social, economic and environmental considerations.

Various authors [Herman et al. 1989; Ayres & Kneese 1990; Freeman 1992] have mentioned the radical nature of the technological transformation in order to improve the environmental performance of systems: they have recommended reducing the proportion of material in the economy using expressions such as X Factor, eco-efficiency, industrial ecology, functional economy, dematerialization, product service-system etc. Today, traditional Eco design approaches either carry out curative environmental assessments (LCA) [Hauschield 2005], or lead designers towards improved solutions by providing guidelines. Both of these approaches, used in the design of complex systems, most often result in global under-optimizations. Designing complex systems becomes a long process of negotiation within the design team. This negotiation is generally based on an initial definition of the system's specifications – specifications that are rarely questioned during the design process.

In the following section we deal with the problem of defining functional units in Life Cycle Assessment (LCA) of complex systems. In the third part we give a theoretical introduction to the EcoCSP method to identify the optimal architecture. In section 4, the EcoCSP approach is applied in the context of designing a new passenger ferry with hybrid technology. Finally we summarize the contributions of EcoCSP approach.

2. Functional negotiation

Improving environmental performances by reassessing product functions

As underlined by [Lagerstedt 2003], environmental performance generally depends on product functionalities. However, from another point of view, the commercial success of a product depends on the functions it offers to users. [Lagerstedt 2003] mentions the balance that must be found between the « environmental cost » and the « functional gain ». Few methodological supports exist in the domain of tools/methods for environmental improvement or hierarchization, and amongst those that do exist; even fewer enable early intervention in the design process. Current methods of Eco design such assessment methods merely identify the causes of environmental problems in order to redesign the product while keeping its functionalities unchanged; this is in contradiction to strategies of radical environmental improvement (X Factor). Achieving a higher degree of sustainable development requires finding a balance between acceptable impacts and necessary functions. [Luttropp 2005] presents different ways of reaching this balance: he favors reducing environmental impacts while increasing the level of the product's functional performance – a win-win situation that eliminates all unnecessary functions. On the other hand, he is critical of the « green fix » strategy (using new materials while keeping all the functions) that result in short term, temporary optimizations; he also judges inefficient the « linear down » strategy (improving environmental impact by downgrading or eliminating functions).

The problem of defining the functional unit in the LCA method

The methodological framework of LCA is governed by ISO 14040; this distinguishes 4 phases. The phase of defining objectives and perimeter of the study requires the definition of a functional unit. The functional unit is the « quantified performance of a system of products to be used as the unit of reference in a life cycle analysis » [ISO 14044, 2000]. By constraining the designer to reason by iso-functionality, the LCA methods naturally hinder to think about products that might have a better balance between environmental cost and functional gain [Luttropp 2006]. In general, the available tools are based on a single criterion: the main function expressed in the form of a functional unit [Lagerstedt 2003]. This means that very different products or concepts can be compared. Consequently, when comparative LCA's are undertaken for products with several functions, it is important to consider the other sub-functions. As underlined by [Reap 2008], sub-functions can downgrade the precision of the reference flows associated with the chosen functional unit and thus decrease confidence in LCA results.

3. EcoCSP approach

EcoCSP is a further development of the CSP/ LCA approach proposed by [Tchertchian et al. 2013].

Constraint Satisfaction Problem

A CSP (Constraint Satisfaction Problem) is defined by [Montanary 1974] a set of variables X, a set of domains D and a set of constraints. Solving a CSP consist instantiating each variable of X, and at the same time satisfying the set of problem constraints C.

CSP solving process

A CSP is typically solved by reducing the domains. Filtering techniques are used to reduce the domain. These techniques rely on arithmetic of intervals [Moore, 1966] and propagation of constraints [Mackworth 1977]. As [Chenouard 2007] points out, using CSP in preliminary design has the advantage of great flexibility for expressing knowledge and modifying models; it resolves generic problems.

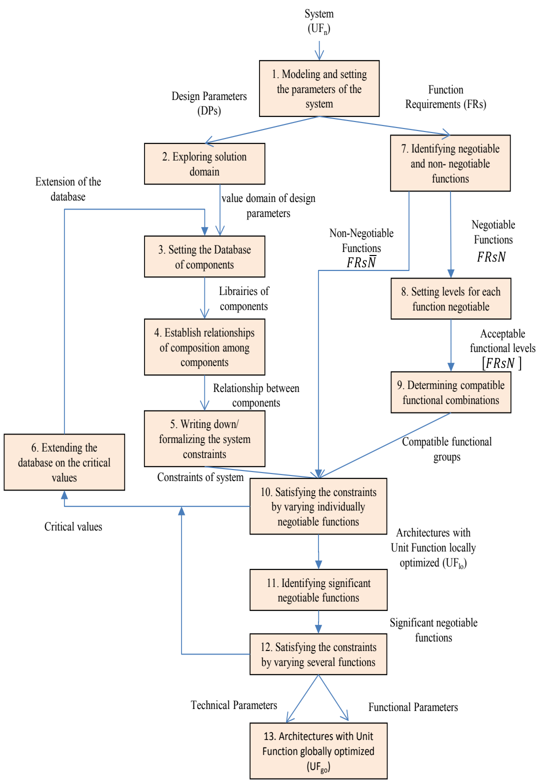

Figure 1: Flowchart of the EcoCSP approach

The EcoCSP approach: a development of the CSP/ LCA approach

LCA uses a normalized functional unit (FUn), to facilitate comparisons among systems that show unequal performances. Our state of the art review and compilation of the main problems posed by LCA [Reap 2008] show that defining a functional unit is not sufficient for the radical improvement of the environmental performances of a complex system. According to our convention, the nominal functional unit (FUn) of a product/system is generally made up of Negotiable Functions Required (FR N) and non-Negotiable Functions Required (FR nN)). The EcoCSP approach enables us to define a functional unit that is globally optimized (FUgo) by modifying the levels of performance of certain negotiable functions. By varying one negotiable function of the system, we obtain a locally optimized functional unit (FUlo).

The EcoCSP approach, as shown in figure 1, is broken down into 3 phases:

- Phase 1: The first phase (2 – 5) consists of determining the technological associations that satisfy the system's environmental constraints.
- Phase 2: The second phase (7 – 9) consists of identifying the negotiable functions and non-negotiable functions.
- Phase 3: The final phase (10 – 13) consists of generating architectures along with their related technical specifications.

EcoCSP approach makes it possible to vary the system's performance in order to reduce environmental impacts.

4. Case study: Passenger ferry

Functional Unit nominal

The system under study is a maritime passenger ferry that crosses the bay of Toulon. The ferry can transport 100 passengers. Taking account of various factors, 300 days of exploitation per year will be used as the functional unit. The ferry has a lifetime of 20 years. The diesel motors are replaced approximately every 12500 hours. The passenger cabin is heated for 6 months in the year and the air conditioning did not work. Phases 1-5 in the general framework of the method (figure 1) and the main relationships governing the system are detailed in previous work [Tchertchian et al. 2013].

Definition of negotiable functional parameters

In first part of the study, 6 scenarios are built by varying a single negotiable parameter (table 1). For each scenario the FUlo corresponds to transporting 2400 passengers per day.

Level	Parameters					
	P1: Speed max	P2: Nb of passengers	P3: Nb of missions	P4: insulation	P5: Air Conditioning	P6 : Nb of charges
Current	12	100	24	No insulation	No AC	1
Acceptable	11.5	97	23	isolation	AC	12

Table 1: Negotiable functional parameters

In the second part of the study, FU_{go} scenarios are obtained by varying the six functional parameters simultaneously according to a design of experiment L_8 (2^6) (table 2).

Scenario	Parameters						
	P1: Speed max	P2: Nb of passengers	P3: Nb of missions	P4: Insulation	P5: Air Conditioning	P6: Nb of charges	FU (Nb passengers/day)
0	12	100	24	No insulation	No AC	1	2400
1	12	100	24	insulation	AC	12	2400
2	12	97	23	No insulation	No AC	12	2231
3	12	97	23	insulation	AC	1	2231
4	11,5	100	23	No insulation	AC	1	2300
5	11,5	100	23	insulation	No AC	12	2300
6	11,5	97	24	No insulation	AC	12	2328
7	11,5	97	24	insulation	No AC	1	2328

Table 2: Globally optimized functional unit scenarios

Simulations

First of all, the CSP/LCA approach is applied to the system considering the FU_n (maximum speed 12 knots, 24 missions daily, 100 passengers per journey, heating for 6 months of the year). The function « objective » is to minimize the environmental impact over the life cycle. Each scenarios described above are assessed environmentally using EI99 single score.

Assessment of FU_{lo} scenarios

The first part of the case study compared 7 scenarios obtained by varying a single negotiable variable. 2400 passengers are transported per day in all scenarios. Speed, number of passengers and comfort are significant negotiable functions because their negotiation allows a significant variation in the system's environmental impact. The distribution of the number of passengers and the number of journeys has an influence on the system's performance. For example, to respect the functional unit of 2400 passengers per day, two scenarios were assessed: 109 passengers transported over 22 missions and 93 passengers transported over 26 missions. While the first scenario allows improving the environmental score by 4 to 5% the second generates 4.5% of extra impact for transporting 2400 passengers per day. Both scenarios have the same FU, but have very different outcomes (Figure 2a).

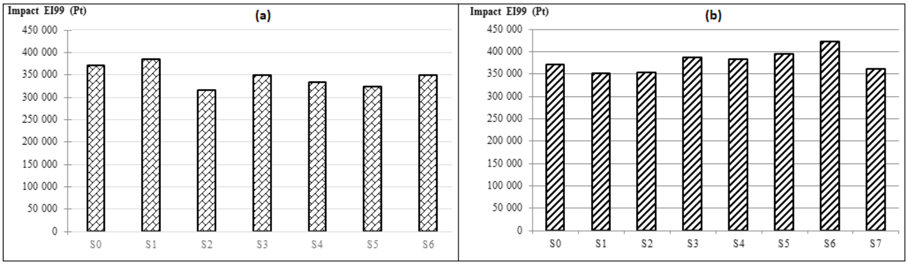

Figure 2: Environmental Assessment for (a) FU_{lo} scenarios (b) FU_{go} scenarios

Assessment of FU_{go} scenarios

In the second part of the study, 7 scenarios were obtained by varying 6 significant negotiable functional parameters simultaneously, in accordance with the design of experiment in Table 2. A small reduction in system performance defined by the FU_{go} results in an environmental gain that can be over 10% (Figure 2b). In addition, this can allow for new functionalities to be added (air conditioning) or existing functionalities to be improved (increased comfort).

5. Conclusions

EcoCSP enables us to anticipate the configuration of a system's architecture by adapting the performances of negotiable functions. A complex system such as a passenger ferry has numerous sub-functions. A slight downgrading of the performances related to these functions can generate substantial environmental gains. The complexity of couplings among sub-systems and their sheer number obliges the user to make use of « intelligent » tools, that by simulating many different scenarios, help the designer to fine-tune and choose the right technologies for sustainable systems.

6. References

[Ayeres & Kneese 1990], Ayeres RU, Kneese AV (1990) Externalities: Economy and Ecology: Towards sustainable development. In: Archibugi F, Nijkamp P (eds) Dordrecht: Kluwer.

[Brezet & van Hemel 1997], Brezet H, van Hemel C (1997) EcoDesign: A promising approach to sustainable production and consumption, UNEP, France.

[Chenouard 2007], Chenouard R (2007) Résolution par satisfaction de contraintes appliquée à l'aide à la décision en conception architecturale. Dissertation, ENSAM, Paris.

[Freeman 1992], Freeman C (1992) The economics of hope: Essays on technical change, economic growth, and the environment. London.

[Hauschild et al. 2005], Hauschild M, Jeswiet J, Alting L (2005) From Life Cycle Assessment to Sustainable Production: Status and Perspectives. Manuf Eng 3:1-21.

[Herman et al. 1989], Herman R, Ardekani S, Ausubel J (1989) In technology and environment. In: Ausubel J, Sladovich H (eds) Washington, DC, National Academy Press.

[ISO 14040 2000], ISO 14040 (International Standard Organization) (2000) 14040 series: environmental management – life cycle assessment – principles and framework. ISO 14040 series.

[Lagerstedt 2003], Lagerstedt J (2003) Functional And Environmental Factors In Early Phases Of Product Development-Eco Functional Matrix. Dissertation, KTH, Stokholm.

[Luttropp 2005], Luttropp C (2005) Strategy and material flow in ecodesign. 12th CIRP international conference on Life Cycle Engineering, Grenoble, France.

[Luttropp 2006], Luttropp C, Lagerstedt J (2006) EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development, J Clean Prod 14(15-16):1396-1408.

[Mackworth 1997], Mackworth AK (1977) Consistency in Networks of Relations. Artif Intell 8(1):99–118.

[Montanari 1974], Montanari U (1974) Networks of Constraints: Fundamental Properties and Applications to Picture Processing. Inform Science 7(2):95–132.

[Moore 1966], Moore RE (1966) Interval Analysis. Prentice-Hall, Englewood Cliffs N.J.

[Reap et al. 2008], Reap J, Roman, F, Duncan, S, Bras, B (2008) A survey of unresolved problems in life cycle assessment. Int J Life Cycle Assess 13(5): 374-388.

[Tchertchian et al. 2013], Tchertchian N, Yvars PA, Millet D (2013) Benefits and limits of a Constraint Satisfaction Problem/Life Cycle Assessment approach for the ecodesign of complex systems: a case applied to a hybrid passenger ferry. J Clean Prod 42:1-18.

[van Weenen 1995], van Weenen JC (1995) Towards sustainable product development. J Clean Prod 3(1–2):95-100.

[Tchertchian et al. 2013], Tchertchian N, Yvars PA, Millet D (2013) Benefits and limits of a Constraint Satisfaction Problem/Life Cycle Assessment approach for the ecodesign of complex systems: a case applied to a hybrid passenger ferry. J Clean Prod 42:1-18.

[van Weenen 1995], van Weenen JC (1995) Towards sustainable product development. J Clean Prod 3(1–2):95-100.

[William et al. 1987], William RE, Larson ED, Ross MH (1987) Materials, Affluence, and Industrial Energy Use. Annu Rev Energy 12:99-144.

[Wimmer & Züst 2003], Wimmer W, Züst R (2003) ECODESIGN Pilot, Product-Investigation-, Learning- and Optimization-Tool for Sustainable Product Development. Alliance for Global Sustainability Bookseries.

Conclusion of the workshop

Anne VENTURA[1], Stéphane LEPOCHAT[2]

[1] Université de Nantes, laboratoire GeM, chaire génie civil éco-construction

[2] Evea, Nantes

The workshop aimed at crossing disciplinary visions about functions. Researchers from various research domains such as design for innovation, mechanical design, life cycle assessment (LCA), functional economy or market economy, were invited to present their work in various application fields: agricultural and food industries, waste management, construction, mechanical engineering and transports. Companies from the automotive and buildings sectors were also invited to explain how they consider functions in their actual practices.

In addition to short articles or abstracts provided by presenters, presentations and exchanges were recorded during the workshop. The audience was very active, engaging interesting discussions. So, this conclusion aims at resuming and organizing all these materials into main aspects.

Crossed visions between disciplines made this workshop very open but sometimes confusing, as it showed that various disciplines used different concepts behind identical words. So first, because of possible confusions, we start this conclusion by defining the term "*product*". A product is often associated to a material good in the common sense. However, in the LCA ISO 14040 standard, a product gathers all goods and services: matter, materials and un-material services. We will take that definition, and, in order to be clear we will precise the term "*good*" for material products, and the term "*service*" for un-material products.

1. How can functions be defined?

This was the first question asked in the introduction of this workshop.

A. Ventura recalled the general common definition of a function in the dictionary as "*the role of an element in an ensemble*" in her presentation. From functional analysis methodology, B. Yannou presented a review that outlined more than 18 definitions of functions co-existing in the literature, in addition to the normative reference that was cited by J. Biziaux and co-authors. All definitions can however be gathered in a global consensus according to B. Yannou as "*a number of co-existing meanings and with the common role of relating goal descriptions of devices with their structural descriptions in a general interdisciplinary way*".

The word "*meaning*" he's been using for that consensual definition is important because it englobes all concepts cited during many discussions between participants in that workshop. The meaning is not only technical it is also psychological, emotional aesthetical or even ethical values, as raised by the participants during the workshop. For instance, the emotional or aesthetical values of products were often cited during the workshop, highlighted by N. Antheaume concerning ethical societal choices for local food markets, mentioned by S. Morel during his presentation about individual vehicles design, as well as by participants about the case of a jewelry product.

Relating goal descriptions of products to their structural description is indeed the work of design engineers. These goals were also called "*stakes*" in A. Ventura's presentation.

However, in the light of various case studies presented during this workshop, it appears that the term "*device*" proposed by B. Yannou in the above definition could be inappropriate, because a device is only linked to a material good, and thus not as general as the term "*product*". Finally, the workshop can lead to the definition of a function as being "*a number of co-existing meanings and with the common role of relating goal descriptions of products with their structural descriptions in a general interdisciplinary way*". This definition seems appropriate to enable inclusion of other aspects than only technical aspects of products that would be reduced to material goods only.

2. Taking distance from material goods

The very first example of the workshop, presented by N. Antheaume and N. Schieb-Bienfait, showed that for local food markets (free range chickens for school restaurants), customers initially expected good environmental performances. After experimenting local providers, customers decided to implement this solution although environmental performances were not improved, because the solution revealed other advantages, mostly social, called "*unexpected functions*" by the authors.

This example highlighted that customers can be inspired by ethical (environmental or social) goals. These goals are not only useful for the user itself, but for a larger part of the society and/or for the environment. These types of functions were called "*external functions*" by A. Ventura. They often concern particular products, where customers are not the users, but entities in charge of collective or other's interests. Customers are local authorities in the above example, whereas end users are children. This type of context is also found in other cases presented during the workshop: waste management (F. Laurent and co-authors), public transport (N. Tchertchian and co-authors), and buildings (C. Gobin and S. Chevallier), for which customers can be local authorities, social services, real estate investors…

In this type of context, the product is not anymore a single material good, but a set of material goods inside a global context, providing services seen as goals by the customers.

As underlined by J. Biziaux and co-authors about functional economy, several upgrading levels can be reached from classical economy based on material goods production and ownership, to pure servicial economy. As said by J. Biziaux and co-authors, at its highest level, functional economy is not focused on single products, but on a complex system of materials goods and services including logistic, informational, social and environmental aspects… dedicated to providing services to customers. The authors underlined that functional economy is basically focused on the search for new business models, but they found it is however compatible with eco-design. The workshop could show from various examples, that including ethical goals could favor the enlargement of the system considered. This situation is favored in a context where customers represent collective interest of end users. However, J. Biziaux and co-authors showed that it was also possible to put in application when customers are users…

3. Functions, users, markets

…Indeed, whatever the customer be, users are thus at the center of the function question.

J. Biziaux and co-authors gave the example of an eco-designed chair that was conceived evolutive to adapt all ages from baby to adult. Reaction of the audience was turbulent about that example. To resume it, some participants said they would not buy such an expensive chair knowing that they would "*have to*" keep it their whole life, whereas they'd rather change of chair for other reasons than only the function of sitting, i.e. giving the chair an aesthetical goal. About this issue, S. Morel was also questioned by the audience. The example concerned diesel family vehicles, of which 5 to 7 seats and long distance autonomy were fully used only a few times a year, for vacations. The most current usage situations of these cars are a single driver and a short distance for daily home-to-work trips. However, he explained that even though small electric vehicles fulfill most of their transport needs, customer may not choose them yet. One explanation is linked to emotional needs (reassurance versus the innovative system).

A. Ventura recalled that functions represent the reason for which a customer is ready to buy a product at a given price. From both construction and automotive sectors present during the workshop, it was agreed that prices were roughly increasing with the number of new functions offered by products to customers. J.-C. Boldrini explored in depth this relationship between functions of products and values attributed by the market. According to his literature review, the value will be produced from the experience of customers-users; a life experience that is provoked by their interactions with a product. Thus, characterization of value appeals for an integration of multiple conceptions of values (ecological, pragmatic, economic, psychological…).

The above examples about the car or the chair could thus be interpreted as a form of "*resistance*" of the customer to environmentally friendly solutions. However, according to B. Yannou it is a deeper problem concerning design. Functions are only elementary actions contributing to larger goals, and goals are those that should be investigated previously to functional properties. Indeed, goals will depend on usage situations, and they should be defined in order to solve problems or so-called "pains" encountered by users. Only information from usage situations can provide desirable goals providing values to customers-users.

There are various methods dedicated to the identification of user's needs. S. Morel presented the Collaborative LCA (Co-LCA) scheme and the "persona" tool. B. Yannou presented the notion of affordances which are defined as "*behaviors or needs that can be afforded once something exists*". There are existing methods taking affordances into to account all along the design process. He gave the example of a fridge showing that functional analysis alone only fewly recovered needs expressed with affordances analysis.

From analysis of goals and needs to quantification of design objectives, B. Yannou detailed methods used in "design for market" approaches that mix techniques for quantitative marketing with design exploration of configurable products. The design model aims at comparing the desirability of products in terms of properties, price and environmental aspects. The market demand model can be developed from several methods such as utility function, fuzzy rules or multi-criteria decision methods. Only utility function has been detailed in his presentation as the most common method.

4. Quantification of usage situations: a driver to innovation

J.-C. Boldrini reminded from recent literature that value is co-created by the interaction of artifacts and all the parties present along the Value chain. With this perspective, the "realm of value" cannot be limited to the product/service itself (the efficiency of the engine in an electric car for example). It must encompass the product/service, its whole environment and all stakeholders (for example, an innovative system of transportation with services adapted in order to limit congestion, pollution and road insecurity in urban environments). So the actors and the social systems have to innovate not only in new goods, new methods, new markets, new sources of raw materials or new organizations, as in Schumpeter's theory of Economic Development, but also in the dynamic interaction among social, natural and artificial systems to achieve sustainable value.

B. Yannou showed many examples of innovation driven by the quantification of usage situations. His examples were mainly focused on material goods products. However, this type of methods should (is?) applied to more complex systems dedicated to servicial economy.

5. Characterizing functions

Well characterizing functions remains a challenge, for both existing and innovative products. Difficulties resides both in specifying and quantifying functions.

According to the work of D. Collado-Ruiz and H. Ostad-Ahmad-Ghorabi, LCA practitioners do not often define Functional Units of products in technical terms, or if they do, they use inconsistent terms and parameters. This was also illustrated by S. Morel with a survey of current functional unit in passenger cars' LCA.

Numerous examples and case studies presented during the workshop showed the difficulty of conducting this task properly. Here are examples. C. Gobin and S. Chevallier showed the multiplicity of functional properties of buildings that are much more than sheltering individuals but also include security, thermal comfort, communication, mobility facilities, and a quasi-infinite list of services one can be waiting from a home…

About buildings, A. Ventura also showed that functions of buildings were "*nested*": the whole buildings' goals partly or totally impose functions to its composing elements, and those elements partly or totally impose functions to their composing materials. This nested aspect could also be observed in the work presented by N. Tchertchian and co-authors where designing a maritime public transport system includes requirements from passengers' needs, ship requirements as well as engine requirements.

F. Laurent and her co-authors, showed that for collective biogas plants dedicated to valorization of organic waste, functions were also multiple between reducing waste, producing energy, producing heat or fertilizers…

D. Collado-Ruiz and H. Ostad-Ahmad-Ghorabi propose a general frame to characterize functions, called the "*fuon*". Their method is a systematic approach to define, both types of functions as well as a quantified value that can be a scaling factor for more "*subjective*" functions. The method has many interests according to the questions raised during the workshop. First, it proves systematic and robust, as the authors explained they had tested it in a workshop with 50 participants and that more than 90% of participants that tested the method gave identical "*fuons*" out of a given product. Second, although the *fuon* was tested for material goods products, it could be suitable for immaterial goods products as well as for more "*subjective*" functions because it allows quantifying subjective elements by a scaling system. Third, the method appears well applicable to collective thinking processes; it could thus be compatible with market design methods dedicated to include usage situations as described by B. Yannou. Finally, because of this systematic frame, *fuons* also seem compatible with nested aspects of multiple functions.

6. Dealing with multiple functions

Multiple functions are necessary; it even seems that multiple functional products are a key to innovation and eco-design. Indeed, every LCA practitioner knows that sharing functions in a single product is the best way to share environmental impacts. No matter the scientific debate between LCA experts about the choice of sharing impacts methods (allocation, system expansion with substitution…), multiple functionality will almost mathematically result in diminishing the impacts of each additional functional properties of a product.

However, comparing environmental performances of products based on same functions, i.e. using functional unit, becomes complicated.

The work of F. Laurent and co-authors was dedicated to this particular question concerning multiple functions of a collective biogas plant. They developed a method aiming at providing goals to the plant according to stakes, analyzed and defined out of territorial specificities. Their method enables providing the most useful function between organic waste treatments, energy production, heat or fertilizing needs… The plant can thus be designed differently according to the main identified goals.

N. Tchertchian and co-authors dealt with the question as well. They were able to define precise values of functional requirements of a whole maritime public transport system, at various interacting scales (trip, boat, engine…) by using the Constraint Satisfaction Problem (CSP) method.

Those methods prove accurate and relevant for complex service systems, with multiple economic actors, stakeholders and decision levels. However, they are not adapted to help consumers choosing between products.

In that context, C. Gobin and S. Chevallier developed the so-called "*building signature*". This visual tool represents scaled values of functions and environmental performances on the same graph. Values should be scaled according to reference values that would regionally specific, as functions and performances of building are linked to territorial aspects such as local materials, climate, cultural habits… The method still seems a challenge to put in application, because, as said by C. Gobin, it requires collecting data and developing a regionalized database. However, according to tested examples, it proves simple to understand by the end-user.

About labeling of agricultural products, H. van der Werf also presented the idea that instead of quantifying environmental performances per kg of product or cultivated area, it could be related to the money spent by consumers, i.e. kg of eq. CO_2 per euro spent for climate change. This idea can be found consistent with the fact that value can be linked to the quality and number of functions offered to the customer, but that is still to quantify. It could also be an interesting aspect for considering rebound effects between products. Furthermore, as underlined by the audience, the influence of such labeling on market prices should also be investigated.

7. Usage situations and products' functions: what is the difference?

As we begin to understand from this synthesis is that functions and usage situations is one of the key aspect.

Let's say that all steps presented in this workshop would be gathered in a global method and would be respected: using first market design to estimate and quantify usage situations, and thus desirability of products, and then defining new ideas and new properties of these products, including (why not?) subjective *meanings* such as ethical or aesthetical goals quantified and organized by using *fuons*.

They would thus have to be tested in a real situation, what was called by A. Ventura "*in situ*" functions in comparison with "*potential functions*" for initially expected functions. This testing period is already provided to users in market design methods as explained by B. Yannou.

However, for complex systems, i.e. those dedicated to collective interests, the question is worth exploring deeper because users are not customers, and because economic actors or stakeholders contributing to the set of functions can be numerous. N. Antheaume explained during discussions that satisfaction of children for eating food of better quality was an important aspect to quantify, although difficult to estimate. A. Ventura also explained that for long service life products, "*in situ*" functions could be degraded with time and that these aspects should be integrated into initial product design. Furthermore she underlined that end-of-life functions should also be accounted at the early stages of product's design.

Furthermore, environmental *functions* can be included in product design however, only environmental *performances* can be assessed by LCA method. Only an iterative method using LCA to assess expected environmental performances of various design options, and then to retro-act on environmental functions, can be used. Environmental impacts are consequences of technological systems, and the fact that they can possibly be considered as "*external ethical functions*" is a customer-consumer-user's choice that does not change the fact that they will be provoked by the product's life cycle. J.-C. Boldrini suggests defining the economic value by estimating the ratio between satisfactions of users and burdens taken from society and ecosphere. This value concept proposed by J.C. Boldrini introduces a divergence because economic value is no more simply linked to usage and/or functional analysis. However, it takes its full scientific relevance by differentiating causes and consequences.

In fact, the main difference between usage situations and products' functions is similar to the existing difference between objectives and performances. Better knowledge about performances should be investigated, in order to better redefine functions, in an incremental wheel.

This workshop undeniably highlighted how to better apprehend functions, how they can drive innovation and opens research perspectives for eco-design.

EcoSD network is a French association whose main objective is to encourage collaboration between academic and industrial researchers so they may create and spread advanced multidisciplinary knowledge in the eco-design fields at national and international levels. Among other actions, EcoSD organizes an annual thematic workshop to enhance collaborative discussions. The present workshop was organized in that frame. It was held in Nantes in 2014. It gathered around 50 participants.

The notion of function in eco-design can have different meanings, according to the discipline (engineering, economy, sociology), and according to the life cycle step. When a product is conceived, eco-designing imposes to foresee the use and end-of-life phases. However, there are differences between the "expected functions", and the actual "usage" of products, that could be compared by analogy to the difference between "supply" and "demand" in economy. This gap between function and usage could be explored to improve environmental performances of products because adjusting the function is a performance axis by itself, as well as to better define comparison basis between similar (but different because multi-functional) products. This problematic is transversal to eco-design: eco-usage, functional economy, Life Cycle Assessment (functional unit and consequential LCA)… It can be resumed by the following key questions: How to define functions? How to predict and quantify functions, utilities and usages? How to compare complex objects?

The objectives of the workshop were to cross different visions from different disciplines gathering the most recent researches in France. Researchers from various research domains such as design for innovation, mechanical design, life cycle assessment (LCA), functional economy or market economy, were invited to present their work in various application fields: agricultural and food industries, waste management, construction, mechanical engineering and transports. Industrial from the automotive and buildings sectors were also invited to explain how they consider functions in their actual practices.

Réseau EcoSD Eco-conception de systèmes durables

www.ecosd.fr

20 euros