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### ► To cite this version:

François Cluzel, Bernard Yannou, Pascal da Costa, Christophe Gobin. The DECADIESE methodology: Extending usage and value creation perspectives of a building by value and externalities management. Proceedings of EcoSD annual workshop 2016 on "How ecodesign of products and services can embrace the use stage?", Presse des Mines, 2016. hal-01448851

**HAL Id: hal-01448851**

**<https://hal.science/hal-01448851>**

Submitted on 29 Jan 2017

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# The DECADIESE methodology

## *Extending usage and value creation perspectives of a building by value and externalities management*

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## 1. INTRODUCTION

Ambitious building retrofits are often hardly justified by energy savings only. A previous research project has shown that dividing by two the energy consumption of a building (like a school) may lead to a return on investment superior to 25 years [RS4E, 2010]. In this configuration, decision-makers are often not inclined to invest. Thus there is a need to investigate in more details and highlight the benefits of such retrofits or new buildings with a broader point of view.

That is why the DECADIESE methodology has been developed by a consortium of major construction and energy companies (EDF R&D, Bouygues Construction, Vinci Construction, Foncière des Régions) and academic partners (CentraleSupélec, Université Paris Diderot – Paris VII, Mines ParisTech) in the frame of a French research agency-supported research project (2012-2014).

DECADIESE considers an extended value of a building by incorporating sustainable dimensions through externalities integration, but also by recentering the value created by a building around the benefits for its users. This paper focuses on the latter. On one hand, costs are broken down into seven usage functions, which highlights possible mismatches between functional objectives and associated amounts of money. On the other hand, the functional performance of the building is assessed thanks to 95 criteria that are then aggregated into seven usage functions scores. Once those elements identified, DECADIESE gives to a project owner the ability to compare building variants.

A complete overview of the methodology is given in section 2, and the functional aspects are explained in more details. Section 3 presents the first results and a short discussion. Finally, section 4 highlights the main conclusions and perspectives.

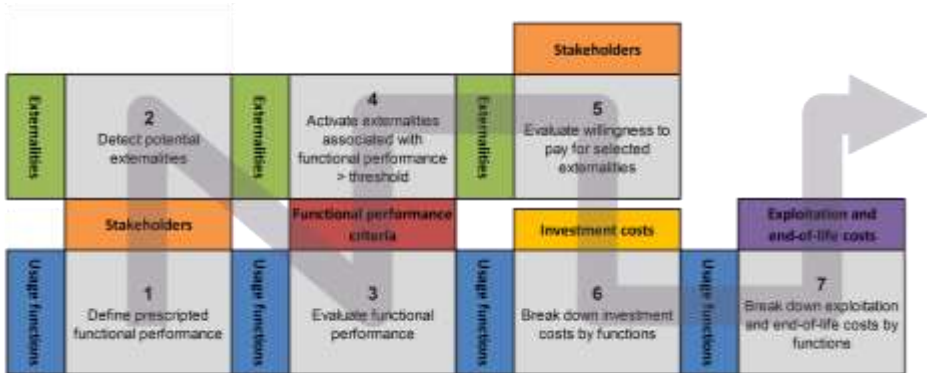
## 2. METHODOLOGY

A general overview is given first. Then the seven usage functions are detailed to introduce the usage function cost and the functional performance models.

### 2.1. Methodology overview

Figure 1 proposes a simplified matrix vision of DECADIESE. Different objects are manipulated all along the DECADIESE process:

- **Usage functions**, which constitutes the reference basis to represent the characteristics of every building in DECADIESE. The functions are detailed in section 2.2.
- **Stakeholders** involved in the building project, but also stakeholders that could be involved thanks to DECADIESE.
- **Externalities**, that are defined as “the cost or the benefit that affects a party who did not choose to incur that cost or benefit” [Coase, 1960; Pigou, 1920]; DECADIESE considers environmental, social and economic externalities.
- **Functional performance criteria** that allow measuring the performance of a building, detailed in section 2.4.
- Investment, exploitation and end-of-life **costs** of the building.



**Figure 1. DECADIESE methodology overview**

The DECADIESE process is performed following these seven steps. It requires a DECADIESE expert (i.e. a person comfortable with building design and trained with the methodology, called the assessor here) able to run the process, the interviews and the different tools:

1. First the DECADIESE assessor helps the building project owner to precise its project by defining expected functional performance levels. Additional interviews with other stakeholders, like local authorities, insurances...) complement this step.
2. Then the assessor detect potential externalities from a list of predefined externalities and interviews with the stakeholders. The idea here is to select relevant externalities associated with the specific building considered in the study (according to its location, its environment...) and that are also

- interesting for the stakeholders.
3. Then the functional performance of the building option(s) is evaluated. This step is detailed in section 2.4. The output of this step is a score from 0 to 10 on each usage function and for each option that can be compared to the expected performance level defined at step 1.
  4. According to these functional scores, some externalities are thus activated: each externality is linked with one or several usage functions. Reaching a predefined threshold on one function may activate one or several externalities that are then studied in more details.
  5. For each activated externality, a willingness to pay is evaluated by interviewing the relevant stakeholders. A concertation process allows defining an extended value vision of the building, where some externalities are valued with preexisting or new stakeholders of the project. The business model of the building becomes more accurate.
  6. Investments costs associated with this (these) building option(s) are then broken down on the usage functions. This step is detailed in section 2.3.
  7. Exploitation and end-of-life costs are also broken down on usage functions, following the same principles.

At the end of this process, a large amount of useful information is available. The participants precisely know the functional performance scores of each option considered, as well as the gap (positive or negative) with the targeted scores. The costs of each function is also known, and it is possible to check the consistency of these costs with the associated functional scores. Finally, associated externalities are valued, and new stakeholders are potentially associated to the project by revealing precisely their benefits and willingness to pay. In this way all elements are combined to allow an ambitious building project or retrofit with harmonized value creation and costs repartition.

The general process of the methodology is explained in more details in [Nösperger et al., 2015]. Functional aspects of this general process are detailed in the next paragraphs.

## 2.2. The seven usage functions

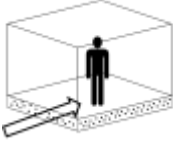
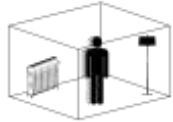
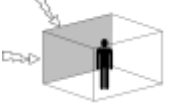




The seven usage functions of a building represents the reference basis to project a building (its performance, its costs, and associated externalities) in DECADIESE. These functions have been identified as an invariant basis on which every building may be represented (whatever the performance is good or not). The seven functions are detailed in Table 1 below. They are called ‘usage’ functions as they allow to reveal the value brought to the user. The seven usage functions are used in DECADIESE to centre value creation on usage and users, to share a common language, and to interface the different objects used in the methodology. They are particularly used to position costs and performance in order to compare different building options.

## 2.3. Usage function costs domain

The breakdown of building costs on usage functions aims at giving to the decision-

makes a new perception of building costs that complements the classical structural breakdown by systems and components. Figure 2 illustrates this principle, which consists in identifying the contribution (repartition keys) of each system or component to the seven usages functions.

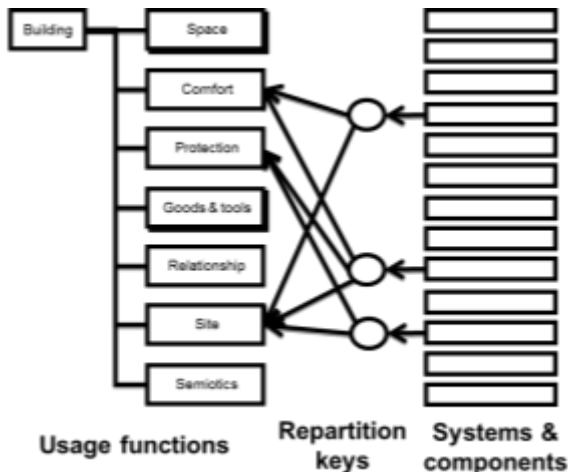
**Table 1. The seven usage functions (adapted from [Gobin, 2006])**

Functions	Subfunctions	Illustrations
To provide <b>space</b>	To have a space to conduct wanted activities To allow the access to this space from the outside	
To provide <b>comfort</b>	To participate to light and visual comfort To participate to hygrothermal comfort To participate to acoustic comfort To participate to olfactive comfort and in-house air quality ...	
To provide <b>protection</b>	To preserve the integrity of people and goods To ensure security against vandalism	
To allow the use of <b>goods and tools</b>	To create surfaces to host goods and tools To provide resources necessary to supply goods and tools	
To control relationship	To allow the user to come into contact with people or to isolate himself To preserve privacy	
To be part of a <b>site</b>	To benefit from the building's location To preserve pre-existing equilibrium	
To have a meaning ( <b>semiotics</b> )	To express to third parties a personal meaning (image) To cause to the user an emotional load associated with balance and well-being (personal feeling)	

This approach is directly inspired by the notion of function costs proposed in Value Management (VM) and Functional Analysis. The function cost approach is precisely defined in VM standards (see for example [NF EN 12973:2000]). The originality of

the DECADIESE approach lies in two main elements:

- Although it is a well-known approach in industry [Ehrlenspiel et al., 2006], it has never been applied to the construction sector with a perspective of decision-making for more sustainable buildings;
- It is generally applied on specific functions issued from Functional Analysis, whereas here it is applied on the seven invariant usage functions.



**Figure 2. Principle of the usage function costs approach [Gobin, 2012]**

In practice, the following process is proposed to apply the approach with a group of multidisciplinary experts from the construction sector. It is based on an Excel tool:

1. **Goal and scope definition:** inspired from Life-Cycle Assessment [ISO 14040:2006], this step aims at defining the objectives of the study, its perimeter, the preliminary hypotheses...
2. **Identification of the contribution of the technical elements on the seven usage functions:** the contribution of each generic system and component of the building is determined by the expert group. For example, a structural pile may contribute at 50% to the “Space” function, and at 50% to the “Protection” function (as it contributes both to create space and to ensure the solidity of the building).
3. **Usage function costs calculation:** once the contribution of each element is known, it is then possible to calculate the total cost of each function by multiplying the cost of each element by its contribution to a function.
4. **Interpretation:** interpreting the results may have different finalities, like controlling that the cost of each function is aligned with the requirements of the building project owner. That is why the assessment of the functional performance is another important task in the DECADIESE methodology. It is explained in the next paragraph.

#### 2.4. Functional performance domain

The assessment of the performance of a building proposed in DECADIESE is also

based on the seven usage functions. The objective of this part is to propose a rigorous framework to evaluate the performance of a building that could be associated with the function cost approach and the externality model.

The proposed model is based on fuzzy logic [Zadeh, 1965]. Fuzzy logic is used here to aggregate several types of functional performance criteria (qualitative and quantitative), based on expert rules with a certain degree of uncertainty.

95 functional performance criteria have been identified to characterize the performance of a building. They are grouped by usage functions and by usage subfunctions (see Table 1). Then multiple expert rules have been identified to aggregate these criteria and to obtain for each subfunction a performance score between 0 and 10. An example of some criteria is given in Table 2. By giving a value to each criteria as input, the model is able to estimate the most probable score between 0 and 10 as output.

**Table 2. Examples of functional performance criteria and expert rules concerning the hygrothermal comfort**

Criterion	Type	Levels
PPD (Predicted Percentage of Dissatisfied), see [ISO 7730:2005]	Quantitative	% of PPD in summer % of PPD in winter
Temperature space zoning	Qualitative	Yes/Partially/No
Equipment affordability	Qualitative	Intuitive/Easy to handle/ Hard to handle

In practice, the following process is proposed to apply the approach with a group of multidisciplinary experts from the construction sector. It is based on an Excel tool associated with fuzzy logic software:

1. **Goal and scope definition**, similar to the previous section.
2. **Calibration of the fuzzy logic model**: the model is pre-calibrated with expert rules. However, it may be useful for some specific application to control the coherence of the rules, and eventually to define new ones.
3. **Evaluation of the elementary performance**: the expert group assesses each of the 95 performance criteria for the considered building option(s).
4. **Evaluation of the aggregated performance**: running the fuzzy logic model then allows the identification of the performance score of each functional subfunction. An optional step is to aggregate these scores by function, or even as a single score.
5. **Interpretation**: as in the previous paragraph, interpretation of the results may have different finalities, the most interesting being to control and discuss the relevance of the functional performance according to the associated function costs. The evaluation of this performance is also the first step for the valuation of externalities, as explained in section 2.1.

### 3. FIRST RESULTS & DISCUSSION

DECADIESE methodology has been partially applied to one specific case study

provided by the project partner Bouygues Construction.

Skyline is a set of three buildings located in Nantes (west of France), mainly intended for office activities, although the ground floor is designed for shopping activities. Skyline was built in 2011 in an industrial area, near the TGV station, in order to create a high standard business quarter. It has several labels: HQE (standing for High Environmental Quality in French), BBC Effinergie (low consumption building). The global investment cost is 60 million of euros. The interesting point with Skyline as a first case study for DECADIESE is that the entire value chain of the building is controlled by the project partner Bouygues Construction (specifications, design, construction, use (partially), exploitation). Data are thus available. The usage function cost model has been applied on Skyline with a group of five experts involved in the development of the methodology. An overview of the results is given in Figure 3. The feedbacks of this first application show the ability of the model to be successfully applied on a real case study. Relevant information was obtained.

The importance of the costs associated with the functions “Space” and “Comfort” is justified (30% and 28%), as providing space is the purpose of a building, and particular efforts were made concerning comfort (highlighted by the labels). The “Relationship” function contribution is small (3%) as it mainly concerns doors, windows and blinds, that have a certain utility but a small relative cost. The contributions associated with the functions “Protection”, and “Goods & Tools” are in accordance with what was expected. The contribution for the “Site” function is negligible, due to the fact the technical elements contributing to the interfaces of the building with its environment were mainly not taken into account. Finally, the “Semiotics” function contributes to 14% of the total costs, which reveal the luxury nature of the building.



**Figure 3. Skyline building and its costs breakdown by usage functions**

These first results also shows some limitations, for example the variability of the results that could be obtained with an expert group or with another. Further work is needed to develop standardized guidelines. The functional performance model will be applied on Skyline in the forthcoming months.

However, in 2015 the realization of a serious game covering the whole DECADIESE process in a simplified version and during one day with invited experts from the construction sector showed a real interest for this methodology and the relevance of the different parts of the model.



#### 4. CONCLUSIONS & PERSPECTIVES

The DECADIESE methodology aims at supporting the design of new buildings or the retrofit of existing buildings with a new approach centred on usage and users. Value management and fuzzy logic are used to assess the costs and the functional performance of an option on seven invariant usage functions of a building. So decision-makers have new information to compare the benefits and costs associated with this option. This approach is associated with the identification and the valuation of environmental, social and economic externalities, with the objective to enlarge the perimeter of stakeholders contributing to the investment, and thus allowing more ambitious sustainable building projects.

DECADIESE is still in development. Next steps will deal with the application of the whole methodology on several case studies (already in exploitation, but also in design), to make the process and the tools more usable, reliable and to validate them.

#### ACKNOWLEDGEMENTS

This project was funded by the French Research Agency (ANR). The authors gratefully thank all the contributors of the DECADIESE project, especially Géraldine Roesslinger (Vinci Construction), Bruno Linéatte and Roland Le Roux (Bouygues Construction), Stanislas Nösperger and Jean-Luc Mazoyer (EDF R&D).

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