Eco-Models

Modeling of a digital tool to design sustainable buildings

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Abstract. The demand for up to date information and design 'tools' to help architects design more sustainable buildings is rapidly expanding. This demand has led to use various ecological assessment tools as support tools for the design process. The absence of adequate tools which contribute to early stages, as well as the additional costs of tardy modifications, has led us to propose an eco-design support tool. This tool is based on a methodology named "Eco-Model (EM) Method" that focuses on the ecological approaches of a building. This method proposes to consider environmental friendly solutions from the first sketches by proposing a number of micro-solutions, called here Eco-Model or "EM". Subsequently, the study presents the first contour of software based on an EM approach. Thus, the various actors of the design team will be able to browse the useful information for their green projects and so collaborate to optimize the building design.

Keywords: Eco-Models: sustainable buildings; design support.

Introduction and context

The context in which environmental design happens is complex. This complexity is related to a large quantity of operations and impacts to take into consideration. Any object of design cannot be concerned as one isolated object. It should be apprehended from various points of view to reduce the risk of disregarding possible environmental impacts. The design team has to cope with problems containing a high number of variables. The combination of such variables can probably give billions of possible solutions. Even if it's possible to easily discard a great number of those solutions using "common sense" (feasibility, economy, use, etc.), it is also possible to use a method to quickly choose the most satisfactory solutions to explore.

In this particular context, a sustainable building, being a result of environmental design, should be as integrated as possible with its environment. This means that it should be water conserving, non-toxic, and energy efficient, with high-quality spaces and recycled materials and also to propose long-term solutions for large part of resource and emission problems. This integrity requires a continual adjustment of solutions with their contexts, all along the design process.

In recent years, energy saving and environmental optimization are crucial issues in building design. Several professionals and academics propose to re-evaluate the way that buildings are designed and produced (Metallinou, 2006). This is why this subject has been treated widely in the literature through many approaches, such as multi-objective optimization, ranking methods, index-based methods, and other quantitative methods like cost–benefit analysis. But the majority of these approaches evaluate only the finished building design or at least the advanced stage of design. However, environmental building assessment methods are more useful during the design stage

when any impairment for the pre-design criteria can be assessed and incorporated at design development (Ding, 2008). For this reason various ecological evaluation tools are improvised and used in many cases as design support tools (Cole, 1999). “Rating system provides an effective framework for assessing building environmental performance… as it can be used as a design tool…; it can also be used as a management tool…” (Castro-Lacourture, 2009). This situation demonstrates the absence of adequate tools that are indicated in the early stages of building projects before anything be completed.

This research evaluates existing approaches to disclose environmental knowledge and approaches to provide design support in design processes. This evaluation, along with the increasing request of this type of tools and the additional costs of evaluation induced by the design of green buildings, led us to propose an eco-design support tool focused on ecological approaches of a building project. Particular attention is given to energy aspects in order to improve the energy-saving potential of buildings. Our research is implemented in three phases: first, the proposition and identification of the method of “Eco-Model” or “EM”; second, solution modelling and relations study in the context of building design, and finally, the application of this method digitally. We think that using the EM method is relevant and provides a better solution than other approaches.

State of the art

Due to recent environmental, social and economical crises, various norms, factors and standards are defined by government's sustainable development strategies. Such legislations have led to the rapid increase of the number of low environmental impact or 'green' buildings constructed. Consequently, the demand for up to date information, guidance and “design tools” to help property professionals procure greener buildings also continues to grow (Shiers, 2006).

On the subject of design tools, there is a clear distinction between what reveals from the “proposal” or the possible solution and what concerns the “evaluation” of the proposal. Most of present tools and methods take evaluation into consideration to respond at this information demand with post-evaluations, as well as pre-evaluation and predictions.

Concerning the proposition aid tools and methods, we can find for example the shape grammars with the generative type of tools. We can also mention to creation aid methods, like as TRIZ (russian acronym for Theory of Inventive Problem Solving), which are based on the basis for creative innovations that advance technology and reduce time to market. These types of tools are less operational in the architectural field. The reference based systems seems to be more useful to help solution proposition in a design process. The numerous applications of this approach prove its usefulness. Goldschmidt (1995) in visual display for design explains the importance of analogy and databases of visual images in an architectural design process. Scaletsky (2005) argues the importance of references and the eventual role that they can have in an early stage of architectural design. We think that the efficiency of case based design or reference based design approaches is to re-use anterior solutions in the analogical mechanisms.

Regarding the evaluation aid approaches, we can mention to the “HQE” in France is one of these approaches. This is a building certification which takes into consideration environmental issues during construction operations. It proposes 14 targets to respond at eco-construction, comfort, eco-management, and health.

Also, “high energy efficiency” is another approach created to label building efficiency in five categories: HPE (High energy efficiency), THPE (Very High energy

efficiency), HPE-Renewable energies, THPE-Renewable energies, BBC (Building with low energy consumption).

Many building designers and property professionals do not use environmental tools on all projects because of time considerations and the disruption caused by having to take an 'extra step' in the design and specification process. (Shiers, 2006)

The pre-evaluation and predictions approach is intended to evaluate design performance during the conception stage. Here, an example of a tool is “equer” (IZUBA)1. It is a prediction tool to evaluate environmental impacts before the final concept. However, it doesn’t propose solutions for design aspects. The ECOTECT software is another example of prediction tools. Aimed primarily at architects, this software optimizes a relatively simple and intuitive 3D modeling throughout a vast range of features, like as shading design, solar analysis, acoustic analysis, thermal analysis, ventilation & air flow, resource management. Multiple result comparisons should be done throughout the design process. Its efficiency is better when analyzing a design object from various points of view and at the early stage of design. For example, a new window can be added in order to see its effect on day lighting, thermal response and overall building costs (Roberts et al., 2001). However, this approach seems to cause many drawbacks during the design process because, firstly, it needs to be developed to an extent of producing 3D models, and second, because it is based in trial and error to achieve the appropriate results.

In the evolution of the classical design process, knowledge about efficacy and integrity of choices and decision impacts increase throughout the design process, but on the other hand, liberty of changing and decision making decreases and becomes increasingly expensive and annoying. So we think that it is better to have a digital tool that steps in the front-end stage of a design process. This tool should be able to enlarge environmental-architectural knowledge to help designers produce more innovative environmental projects. Our research, based on the aforesaid, proposes an approach named “Eco-models method”.

Eco-Models Method

During the first phase, this research proposes a methodology to consider environmentally friendly solutions from the first stages of building projects. This approach could be addressed by proposing a number of energetic micro-solutions, called here Eco-Model or “EM”. An EM forms a solution or is a quality-approved form-solution, able to be re-used in an efficient way. Various technical aspects and criteria for achieving a green building project are discussed in this phase.

The various examples of vernacular architecture, conventional architecture and architecture in project are studied to identify EM. Figure 1 presents a number of identified EM. throughout these three kinds of projects.

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1 IZUBA énergies, Développement : Renaud MIKOLASEK, Thierry Salomon, Stéphane BEDEL http://www.izuba.fr/equer.htm

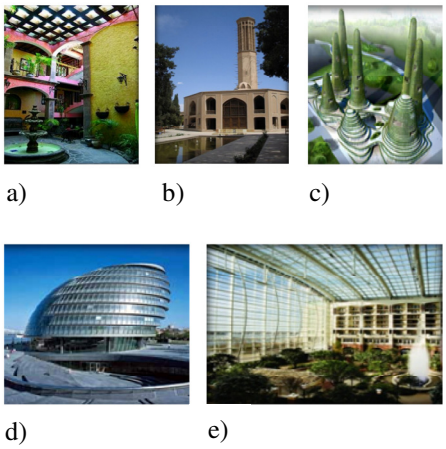


Figure 1
Example of identified EM. from different architectural projects: a) "PATIO" from Posada las Flores in Loreto, b) "WIND CATCHER" from Dolatabad Garden in Yazd, c) "SUSPENDED GARDEN" from futuristic city in Korea, d) "CIRCULAR FORM" from London town hall, e) "ATRIUM" from Gaylord National Resort.

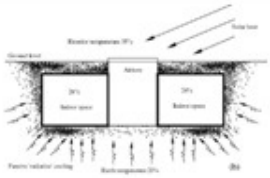
The proposed method is based on the "pattern language" approach, defined by Alexander (1977). Christopher Alexander and his team have defined close to two hundred urban, architectural and construction patterns. Any pattern was presented with a name, a problem and a solution. Then, they have implemented these patterns in a relational system to produce a patterns language. This approach is both used in architecture and in data processing.

The Eco-Models method encourages building owners, architects, engineers, and design professionals to build by advanced knowledge and innovation in the sustainable building industry.

The result of this phase is the identification and definition of different ecological solutions for sustainable projects. A solution feasibility study is done with relevant literature and illustrative building examples. The literature review ensures scientific exactness of solutions and examples to eliminate the implementation weaknesses of the theoretical approaches in real contexts. Afterward, EM. are materialized by an image library and also through the development of use-case scenarios.

EM 1

Underground architecture



Information

Problem: Temperature difference

Solution: Use of the inertia of ground

Exemples

N°1- L'Université d'Ewha (Corée du Sud)

N°2- Parc Vulcania :Une architecture aux 3/4 souterraine

N° 3- Canadian War Museum (2002-2005), Ottawa, Canada

HQE Target

C4- Energy operating, C9- Acoustic comfort **(inclusion)**

C10- Visual comfort, C13- Sanitary quality of air **(exclusion)**

C1- Relation of building with its immediate environment **(cooperation)**

Actors

Research department - Architect- Heat engineer- Civil engineer- Soil mechanical engineer

Physical parts

Equipment, Partition and access, Structure, Adaptation

Spaces

External access, Interior yard, Circulation, Roof garden, Sanitary spaces

Others EM.

Agriculture soil saving **(Inclusion),**

Natural light source, Open space at south **(Exclusion)**

Atrium **(cooperation)**

Figure 2

EM visualization

Such as case-based design aid for architecture (CBDA) (Domeshek and Kolodner, 1992), the importance of EM models is the usefulness of past experiences during conceptual design. Conceptual design is the very earliest stage of design, during which the main tasks are analyzing the problem and forming initial commitments towards a solution. Providing easy access to descriptions and evaluations of previous designs (e.g. existing buildings, with their strong and weak points) would be a major aid in those tasks.

Eco-Models Tank

In the second phase, a demonstration of relations and impacts of choosing any EM is done in an “Eco-Models Tank”. An “Eco-Models Tank” is a database of architectural references that aims is to highlight "best practices" in ecological project design.

In fact, an Eco-Models Tank is a data base in development that saves all information about solution chosen as an EM and its needs and efficiencies. It is in this phase that we re-evaluate environmental advantages and limits of any EM rather than HQE. This re-evaluation can help us to better define if the solution responds to our own environmental needs from an EM or not. Without any doubt, this relational re-

evaluation leads us to an environmental comparison of different EM. and facilitates choosing the solutions. It is what we need to find the better solution in the complex context of environmental building design.

In the Eco-Models Tank, some of the EM. concerned data is described by images and relation diagrams (using UML) from five points of view:

- the building concerned physical parts to address the difficulty level of materializing each EM,
- the involved actors to achieve the EM solution decision and design,
- each EM high environmental qualities, in the French environmental building construction reference ("HQE"),
- the necessary architectural spaces to design,
- the relation between different EM.

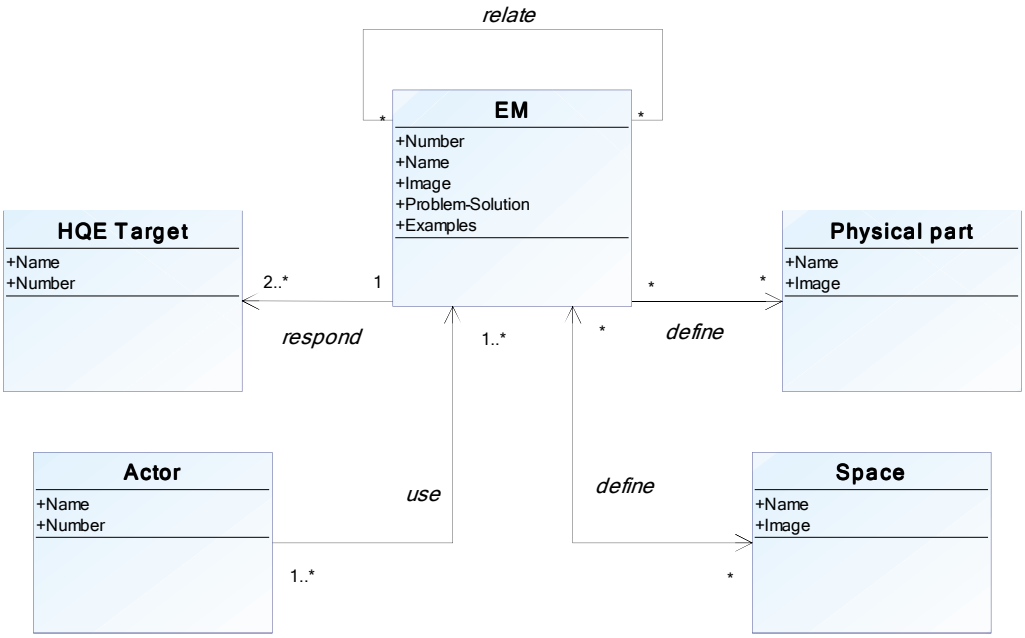


Figure 3
Class diagram of the points of view of an EM information

The relations between EM. can help users to better understand any EM. Like as in the linguistic domain that words give the "context" that allows a reader to make an educated guess about the meaning of an unfamiliar word in the sentence, in the pattern language methodology, any EM which is no familiar to a designer can give meaning from other EM. in relation with it by a natural language grammar (using NIAM: Natural language Information Analysis Method)

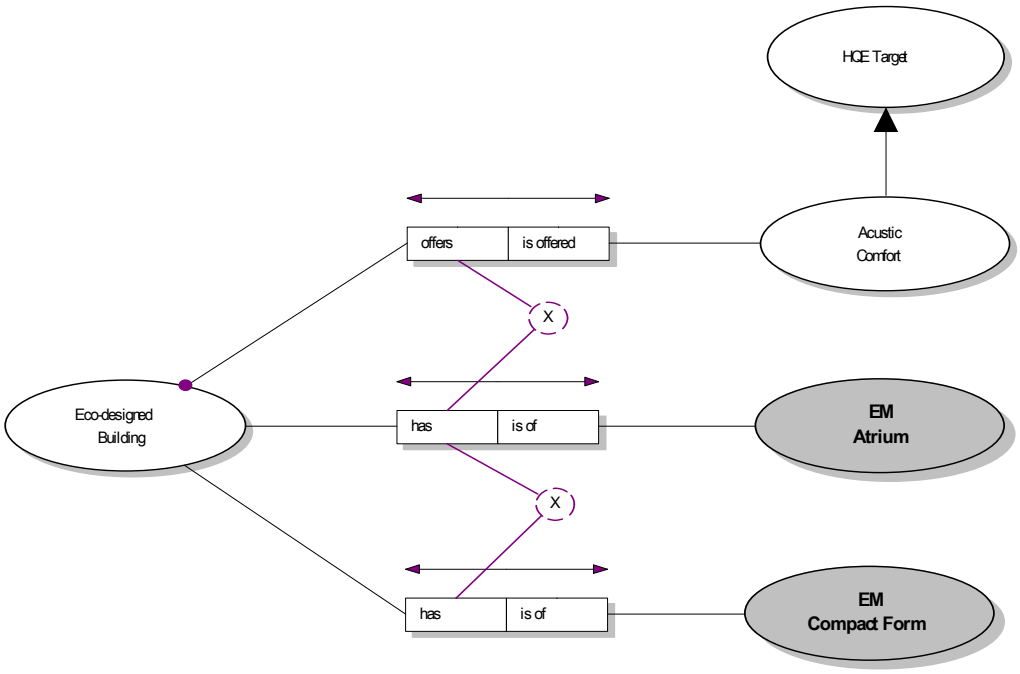


Figure 4
Exclusion relation between two EM, also between an EM and a HQE target

The relations between different EM. could be inclusion, exclusion or cooperation. An inclusion relation between EM. means that using an EM conducts us to use another EM too. An exclusion relation means the impossibility or difficulty to solve for using simultaneously two particular EM. Finally, a cooperation relation is when one or more EM. could satisfy a common requirement. This relational network can simplify the choice of adapted solutions within different situations.

In addition, analyzing EM from five different relational views reduces the risk of believing that the indexed solutions are viable in all situations. This Eco-Models Tank simplifies navigation in an EMs catalogue, presenting various solutions to environmental requirements, allowing the design team a better formulation of its needs and to build their own “choice space” regarding their design context.

Digital tool for eco-design

Subsequently, the study presents a first prototype of the EM-approach based software. To simplify the consultation of this data base (Eco-Models Tank), a digital support is developed. Thus the various actors of the building project design will be able to navigate and find useful information for theirs green building projects. This possibility to define several scenarios helps the design team to evaluate in real-time the impact of its choices in terms of ecological projects management. Finally, this digital support could be adapted to the technical evolutions, architectural and data processing possibilities.

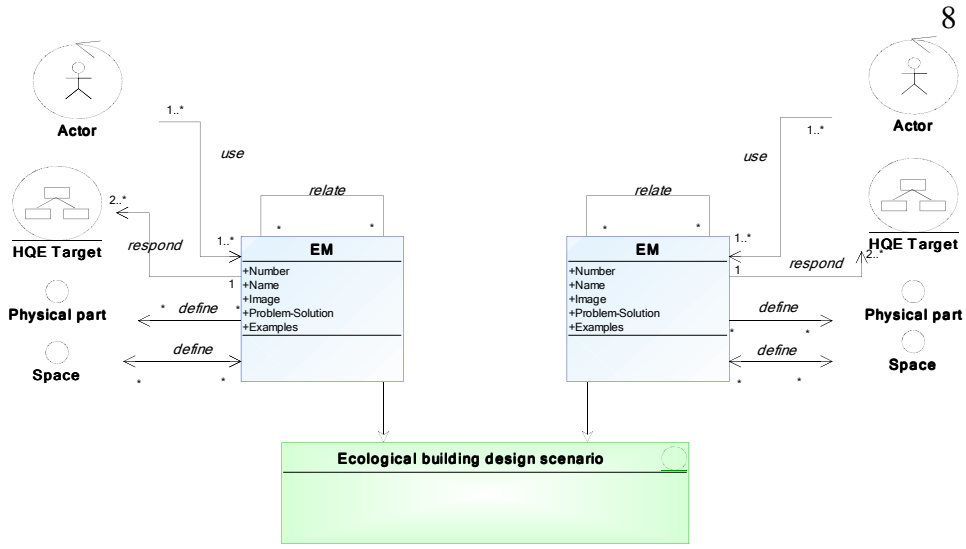


Figure 5
Schematic representation of the scenario modeling tool

Conclusion and perspective

This paper describes the Eco-Models method that can help a design team to find better solutions for their problems using a digital support. The main feature of this tool is the ability to store, share and exchange knowledge through its EM. data base.

This work doesn't focus on problem modeling but in solution modeling. One of our perspectives is to test our proposal on several green building project designs. A tool test and an evaluation of this tool in a real situation are envisaged.

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