Sustainable building life cycle: approach model and construction techniques

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ABSTRACT: In the framework of experimental research studies in the field of sustainable development, the Engineering/Architecture-UE Ph.D. program developed by the University of Pavia is aimed to introduce an approach method concerning the theme of control aspects of building process, with particular consideration of construction techniques and detail project.
The present lacking situation of agreement between design, execution and maintenance moments of buildings needs the definition of a simple method of interpretation able to allow an easy procedure of choice in order to extend the sustainability principals and application methods at design and construction widespread scale.
This kind of approach is based on the definition of measurable indicators and parameters able to allow the comparison between different design solutions on the base of increasing levels of sustainability. The model gives an evaluation instrument that can combine performance characteristics, cost and benefits analysis and maintenance strategies of the principals construction elements, looking to the specifications of all single material chosen to answer at the design hypotheses.
The expected result is the definition, on the base of objective technical specifications, of a procedural approach model at low energy architecture concepts that can match all the factors that are involved in the complexity of the integral building design process using easy to apply and to spread criteria.

Keywords: multi-criteria analysis, construction techniques and materials, indicator method and evaluation model

1. INTRODUCTION

The present dynamic of development in building technology is characterized by a critical lack of agreement between design and realization moments because of the introduction of new performance requirements and innovative building components. In the past these two important stages of the process were mediated by traditional techniques and historical knowledge of materials' energetic specifications.

This state of construction art, increased by the possibility of using new systems and easy to find data, opens to designers new ways of approach, but also new difficulties in checking up and control performance's aspects. At the present time, the greater part of new requirements concern with passive and low energy architecture in order to preserve our environment, together with not renewable resources and economic features.

The present request of flexible and good energetic performing buildings takes designer to consider new design hypotheses with an increased level of complexity in technological solutions, building components and materials [1]. In this situation all the aspects that concern building's shell are the most interested in innovation and their design needs more attention and specification. The main element of this changing is the construction elements' transformation from simple and traditional to complex and active in energy saving applications (Fig. 1).

Figure 1: On the left, roof's construction realized with wooden structure and without insulating material. On the right, multi-layer roof's construction based on energy saving principals. This technological solution is made of good performing and natural materials like as wooden insulating panels and transpiration sheets.

In this preliminary introduction of application field is easy to understand how detail design, together with morphological and context specifications, represent the first attempt to find some answers to energetic and environmental contemporary questions. All these elements show the need of guiding designers' selections between a wide possibilities of materials and application techniques because they are often based on consolidated rules that are very distant from sustainable and quality architecture's principals. For all these reasons is very important to define support approach methods to building solutions' design able to permit a widespread diffusion of new construction choices that can be sustainable from energy saving and environmental aspects' point of view, but also in indoor quality and maintenance specifications. The will of extending, trough the definition of a simulation algorithmic instrument, this new principles to diffused scale and to easily repeatable applications is the final goal of the present research studies.

2. METHODS AND TOOLS

2.1 Context of application

In order to stress the contemporary need of solutions to environmental and energetic problems, the research studies in course of development in the context of the Engineering/Architecture-UE Ph.D. program developed by the University of Pavia aims to define a synthetic evaluation method of technological solutions according to sustainable building design and energy saving principles.

The expected final result is the possibility to introduce, using objective and easy to find technical specifications, a support tool for selection and comparative evaluation of different detail solutions (Fig. 2) on the base of the general theme of sustainable design and responding to the provisions of the European guiding lines concerning energy performance of buildings [2].

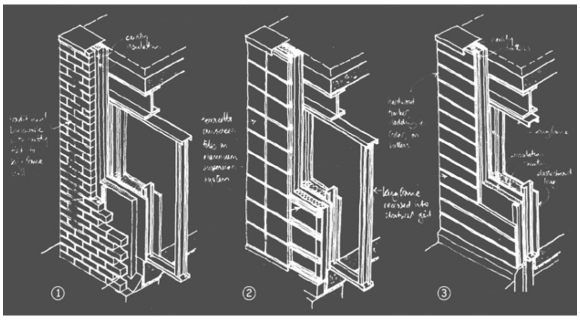

Figure 2: Different detail solutions for the same building's construction element. The possibility of having an easy comparative instrument represents an important support tool to designers' choices and proposals according to energy saving principles [3].

In the framework of sustainability rules, the building system needs to answer to requirements' changing trying to find easy to apply and to spread criteria for some possible design solutions that compose the final construction. The field of typological choices together with technological solutions must respect the cultural and environmental context on the base of using local and traditional materials with the final goal of reducing pollution and energetic needs, but not giving up architectural and indoor quality [4].

This characteristics of transversal complexity of sustainability's guide lines concern all the aspect of buildings' design and construction: the choice of the intervention area, the context analysis, the definition of the final orientation considering the sun process, the morphological and typological strategies, the selection of adequate technological solutions and materials, the design of best fitting systems, the building management and maintenance, together with its final dismissal with disposal of demolition's waste.

Starting from these important considerations and knowing that only the interaction of all these aspects can match high quality results, the research will focus on design of technological elements and construction details of building shell. This final choice is fixed on the acknowledgement that every good design must always be in strict relation with building materials ant all the specific procedures used for their application in construction field.

About this specific theme the Italian architect Renzo Piano says that in every architectural process the designer must start from thinking about materials and their interactions, because "one of the relations with climate, tradition and context is represented by matter". It is very important to support material's production and execution techniques with a new sensibility in their application, not only from technical point of view, but also concerning creativeness and architectural aspects [5].

2.2 Evaluation tool and performance indicators

The specific approach method will define a support instrument to design and evaluation, towards comparison, of different construction hypotheses on the base of the characteristics of every single layer that compose the technological element.

The will is the possibility of implementing an analytic evaluation model founded on objective data towards measurable parameters that don't require specific scientific knowledge and high specialization, in order to extend passive and low energy techniques at widespread scale.

Knowing the complexity of design context and its fast increasing changes, the final expected result of the present work will not be the specific design of technological solutions' details, but the definition of a systematic and fast evaluation tool for building process' operators in order to support their choices between different solutions for the same construction element. The study starts with the choice of application context concerning geographic location, reference body of legislation, functional destination and morphological features of designed building.

After this preliminary stage, the first step of this kind of approach is the definition of synthetic performance indicators and all their relative measuring and comparison instruments. These fixed indicators are able to give back a knowing and organic view trough different mutually exclusive solutions according to sustainability's multidisciplinary target. This last considerations allow the designers to orientate themselves between different design hypotheses with the goal of getting final realization's best quality.

The assessment tool must combine performance characteristics, cost and benefit analysis and life cycle strategies of widely diffused and applied construction elements, on the base of the interpolation of the specifications of all single material that builds up the solution itself. In consequence to this first schematic distinction, the evaluation model is based on three different performance indicators that can control the technological system according to energy saving programs, aside from the specific solution's layers and materials. Some testing applications of adequate solutions can be considered as benchmark of the evaluation instrument (Fig. 3).

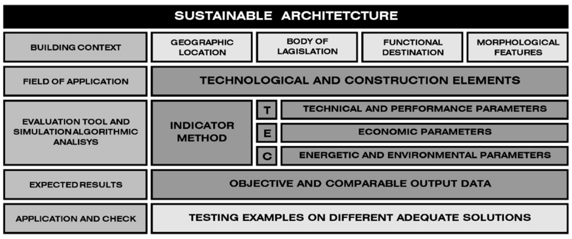

Figure 3: Synthetic scheme of research's stages starting from sustainable architecture's general definition and its making explicit towards all parameters that are involved in building's process. In particular the study considers technological and construction elements' specifications whit the definition of an indicator method able to compare, towards a simulation algorithmic analysis based on objective input data, different design solutions.

The first indicator, called **T**, is defined on the base of technical and performance parameters, together with morphological characteristics of all materials that compose the solution took in consideration. This fixed synthetic indicator represents all measurable data of the specific material, from geometric to performance features.

These kind of data can be usually found in the product's technical specifications' report and so they are easy to find by the widespread process' operator. The will of having a simple tool of evaluation guides the choice of using scheduled data that every designer can find without specific technical knowledge and particular measurement instruments.

This input specifications are going to be easily found in the next future because they are issued by European laws about certification and circulation of building components in the European Common Market.

The second indicator, called **E**, represents economic aspects and is founded on the evaluation of production and installation costs of single components on the base of the analysis of all benefits that the adopted solution can produce. Just like as the first indicator the model will consider cost's values of every single material that compound the construction elements.

This type of information can be found in the tables of building materials' prices, but they can be also obtained from building components' producer in order to use the exact market prices as input data.

This specific indicator is very important for its characteristics of integration, towards weighing parameters, between the chosen solution's starting costs and its induced benefits. This benefits can be, for instance, building's optimization of working management aspects together with energetic need's reduction.

The third indicator, called **C**, corresponds to building components' energetic and environmental features. In this case the input data will consider all the elements that are involved in the energy balance of building components along their complete life cycle. In order to fill this field of analysis the designer can use the results taken from Life Cycle Assessment evaluation method [6]. This process works towards objective integration of building materials' environmental characteristics in order to give back parameters of evaluation of energetic needs for all the stages that compound products' whole life. The possibility of using objective data allows the widespread operator to consider in the evaluation process the specifications of energy consumption for production, working and final disposal phases of building components. The Environmental Product Declaration, based on voluntary action, let designer to compare these data on the base of objective features in order to choose adequate solutions at the specific construction needs (Fig. 4).

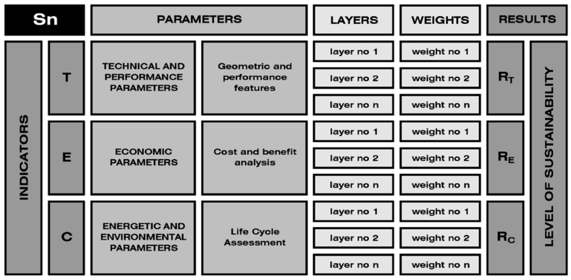

Figure 4: Operations' synthetic scheme of simulation algorithmic model based on indicators method. The will is the possibility of measuring different design solutions' level of sustainability with weighting interaction between technical and performance, economic, energetic and environmental parameters.

In the first step of the research study, the evaluation tool's operator, in the executive phase of design process and in particular in the choice of technological and construction solutions, can find back comparable output data fixing specific performance indicators as input data. Towards a specific simulation algorithmic process, in course of technical definition, the spread designer can find as final result the level of sustainability of different solutions in performance, economic and energetic fields of his design hypotheses (Fig. 5).

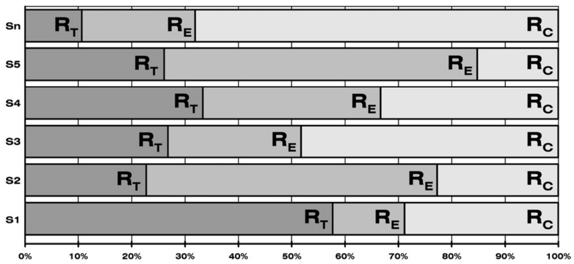

Figure 5: Graphic representation of the possibility of comparison between different solutions on the base of measuring the different per cent levels of the three indicators' final results. The designer can easily

choose from different design hypotheses considering the technical, economic and energetic level that the specific situation requires. From this representation is possible to note how solution number 4 (S4) is the one that can better mediate all the sustainable architecture's different requirements.

At this stage of the defined methodology, the chosen field of application is housing, with particular reference to building's shell. This choice is justified by the will of working at widespread scale in order to involve the largest number of operators in this new energetic and environmental consciousness of the construction process. In addition to this, there is also the fact that at the present time housing represent one of the most important factor in energy wasting and environmental pollution. In order to fit the evaluation tool, as a first approximation, the input data refer to a precise geographic context ('Val Padana' climatic zone [7]), in order to adequate the general model to existing realities and traditions together with the will of balancing parameters and weights to a specific building area.

Different graphic representations can easily give back to the operator the final comparison between all different possibilities with the definition of lower limits of sustainability that must be respected in order to gain better energetic quality of construction (Fig. 6).

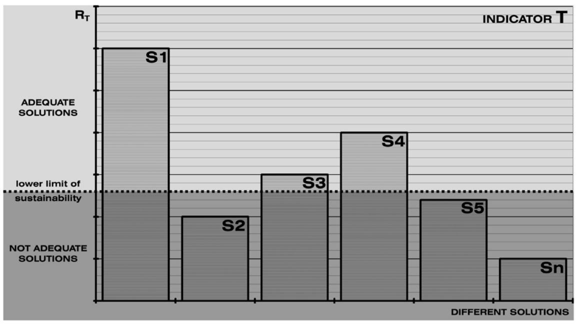

Figure 6: Graphic comparison between different solutions on the base of **T** indicator's final results. The same representation can be realized for the other two indicators. Fixed lower limit of sustainability gives the distinction between adequate and not adequate solutions in order to consent the simple interpretation of results (in this case only S1, S3 and S4).

Using synthetic radar axial representation, the designers can readily measure their hypotheses' global energetic behaviour on the base of three easy to find and to know performance indicators.

The final target is the possibility to have an objective comparison between different solutions without giving strict and fixed rules, but leaving to designer the freedom in choosing the most adequate answer to building context requirements.

Only disassembling the process' complexity in easier controlled parameters can support the design process in reaching coherence with environmental sustainable concepts (Fig. 7).

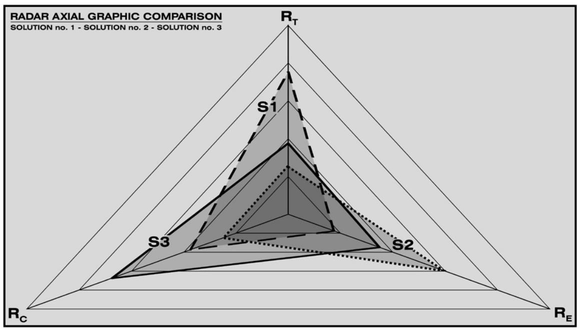

Figure 7: Radar axial representation of results' values for three exemplificative solutions. It allows easy and fast comparison between different design hypotheses.

3. CONCLUSION

In conclusion the approach research at the wider and more complex theme of passive and low energy architecture, wants to find an easy to operate and flexible evaluation tool using multidisciplinary and objective input criteria in order to answer at the present need of definition of a widespread method of comparison of different design solutions in the sphere of energy saving principles. This model, after an adequate testing period, can be easily implemented with input data that can represent different contexts and their specific features in order to use innovative solutions and materials.

The final will is to match all subjective characteristics of architectural design process with all objective topics of energetic and environmental analysis, in order to give to widespread operators an easy to operate and to implement support tool.

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