CONTRIBUTION OF INNOVATION TECHNOLOGY TO SUSTAINABLE CONSTRUCTION


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Summary

The sustainable challenge in building construction has brought new requirements the building design has to provide to. Innovation is not only a matter of technologies, but also of ideas and building conception. In the same time new elements should be considered in evaluation phases to implement the existing assessment methods or to give new ones.

Keywords: Innovation, sustainability, geralized cost, assessment, building quality

1 Introduction

Achieving a sustainable dimension in architecture, as part of a suitable sustainable future, is a challenge that is not only connected with the idea of an energy conscious building or a reduction of environmental costs during its realization, but also with the idea that the impact of building's process conception would deeply influence either the design phases or the management ones.

Nowadays, an innovative approach in building design is the main task of many international known architects and engineers and it is leading to a new way of thinking buildings and using new materials, systems and techniques to build them. In this topic, innovation technology, translated either in new concepts or applications, plays an important rule. Nevertheless, a great attention must be paid to the assessment of some coming requirements of sustainability that could lead to new assessment methods or partially modify the existing ones[1].

A theoretical analysis of innovative contributions in building process using the Extended Life Cycle Cost [ELCC] method has been developed. This study is aimed to define new sustainable requirements, and on a comparative process of existing assessment

[1] For this reason a research program that joints innovation technology, sustainable construction and assessment methods has been activated at IUAV University of Architecture in Venice. Part of this research is led in partnership with the PHD Technology School involving IUAV, Ferrara University of Architecture and Cesena University of Architecture.

methods aimed to upgrade the assessment action with tasks related to design phases and management, maintenance and rehabilitation ones.

2 Innovation technology and the sustainable issue*

When innovation is associated with the world of constructions often its meaning is linked with new materials or new systems. As Martin Pawley reminds (Pawley, 1990) some new materials and techniques had led to epochal changing in building construction, nevertheless another kind of innovation silently feeds evolution of buildings' world. It has been defined “the invisible technology” (Sinopoli, 1997) and it concerns both design and construction process. It has been called invisible because its contribution is untouchable, it doesn't come from using a new material (like Losonczi's Litracon™ for example), or using titanium to realize a cladding curved surface, but it is the result of the relationship between the different “actors” involved in the process whose contributions bring from the building conception to its construction, management, use and so on. In fact a growing sensibility in contemporary building design is leading to foresee what it'd happen at the end of their lifetime, with the so called “deconstruction activity”.

This new task is strictly connected with the time a construction system is expected to preserve his quality. Quality is a concept that is evolving through time with the introduction of new requirements and functionalities involving sustainable strategies.

To analyse the quality of a building in it’s whole complex means essentially to verify the technological solution adopted in relationship with the expected span of life (Manfron, 2005).

The span of life can be influenced by:

- **Technology –** masonry constructions, like most of historic buildings, may have an Expected Life Cycle [ELC] of about 500 years, concrete and steel structures an ELC of about 300 years, balloon frame an ELC of 50-100 years, Hi-Tech is supposed to have an ELC of 50 years. These elements suggest how deep is the link between technological choice and durability.
- **Maintenance –** this activity is not only connected to reliability but also to the design concept of the constructive system to which would have to be referred some parts of evaluation methods. In Hi-Tech and complex buildings, maintenance costs include also the scheduled check activity on components and system behaviour.
- **Rehabilitation –** when this activity doesn’t lead to a loss of the morphological identity of the building it can be considered a sort of extension of building’s life. This allows, with the necessary transformation, to adapt the building to host new functions and to reach a longer span of life.
- **Random events –** represent all that catastrophic events like fires, earthquakes, collisions that can involve a building and modify its expected life time.

As an higher level of durability is not a direct consequence of an implementation of technological complexity, most part of the present research concerns the assessment of recent technologies application, like assembled construction or Hi-Tech, trying to understand how they can influence the behaviour of the building with the passing of the time. As a consequence of this, the attention to the design activity has grown and the conception of the building has become the central point of the analysis.

Conception and design weight strictly depend from the point of view the building process is examined.

There are some Initial Costs [IC], that involve the promoter, the general contractor, the design team, the builder, which can be synthesized as follows:

IC = PC + FC + DC + BSC + CC + …

Where [PC] are the planning costs, [FC] are the financing costs, [DC] are the design costs, [BSC] are the building site costs, [CC] are the construction costs.

When the building is completed, Span of Life Costs [SLC] involve owner, administrators and users as the following:

SLC = EC + SC + MC + RC + …

Where [EC] are the exercise costs, [SC] are the scheduling costs, [MC] are the maintenance cost, [RC] are the rehabilitation costs.

There are also some Long Term Costs [LTC] pending on society like:

LTC = ENC + SUC + SOC + …

Where [ENC] are the environmental costs, [SUC] are the sustainable costs, [SOC] are the social costs.

To achieve a sustainable process means to minimize the following:

ELCC = IC + SLC + LTC.

Unfortunately the decisional power of the different “actors” involved in the process is very different. Financiers operate following economical goals which may be far from social interest for example. For this reason a cultural change in building design is occurring.

To reduce LTC means the growth of other factors in the Generalized Cost Equation.

This probably means a more complex design activity aimed to provide a higher level of performance to the building. When Centre Pompidou was built, Hi-Tech solutions were considered innovative for the flexibility in use of the inside spaces and also for structural and technical choices, but the building wasn’t supposed to bear a so deep change in energy consumption. Contemporary buildings, in e.g. the Swiss Re Tower in London by N. Foster, are thought to minimize energy loss, maintenance costs and especially running costs. This has led to another kind of innovation which regards, as in the Buckminster Fuller’s projects, the idea of a synthesis between building design and technological performance. In the Swiss Re Tower example, the reduction of running costs concerning climate control is obtained with a design conception which allows natural ventilation [Fig.1- Fig.2].

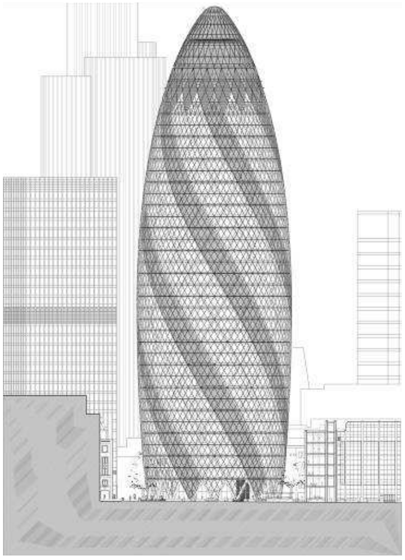

Fig. 1 Swiss Re Tower, London, N. Foster – Each floor-plates is rotated with respect of the one below it, this allows the space between the rating fingers of each floor to combine to form a spiral space which help the climate control through natural ventilation.

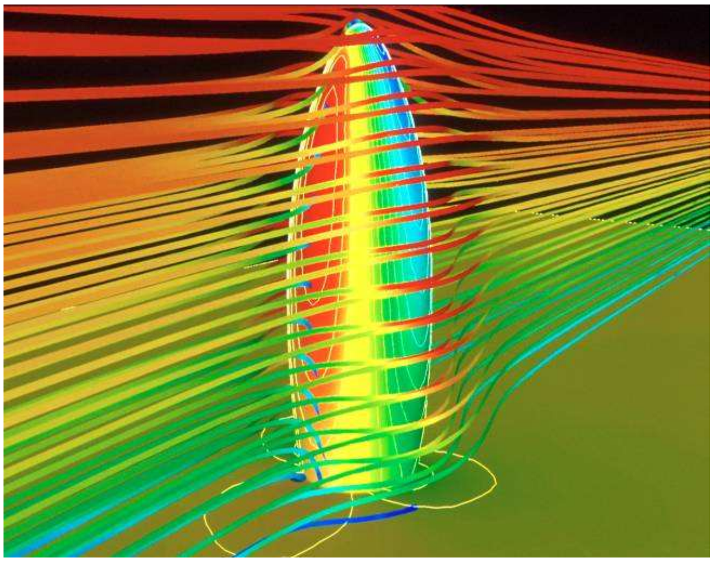

Fig. 2 Swiss Re Tower, London, N. Foster – The outside form is derived from a circular, radial plan which generates a profile that widens as it rises and then tapers towards its apex. The aerodynamic form has been explored in the wind-tunnel to test its behaviour in site condition

The research program focuses the attention to strategies to implement assessment methods with parts concerning design performance, running costs reduction and deconstruction activity.

3 Technological performance and assessment methods**

As Giuseppe Longhi reminds (Longhi 2004), **since "Silent spring" by Rachel Carson had been published in the 60s, the debate about sustainability developed between the concept of the environment value ("the limits of growth", Club di Roma, 1968) and the concept of the human value ("the limits of poverty", Fondazione Bariloche, 1972) (Longhi, 2004).**

Brundtland Report, Agenda 21 on Sustainable Building written by CIB, the latest CIB Sustainable Building Conferences in Maastricht (2000), Oslo (2002) and Tokyo (2005): all such events debate on the relationship between these two aspects which must be balanced.

The complexity of the building process derives from the breakable relationship between built environment and natural one. This complexity is increased by the growth of a request in using friendly environment building techniques and systems as well, with the aim o reduce building process loads to the ecosystem.

As physic parameters like ventilation, cooling, lighting, acoustics, are studied to measure microclimatic aspects and indoor comfort, new concepts are introduced to evaluate physical, metrical, energetic links between constructions and surrounding environment in order to define a "Sustainable Quality" which is nowadays an unavoidable requirement in the building process and becomes a necessary decisional strategy for designers, users and investors.

The rule UNI[2] 10838/1999 defines a "building" as a **"plurality of integrated building products organised such to satisfy at the same time some demands, precise constraints and limited resources into a specific environment"**. A building is composed of spatial elements and technical elements strongly connected each others. Both of them are characterised by a plurality of performances that are assessable to recognise a level of sustainability (or un-sustainability).

Sustainability mustn't to be interpreted as an aim, but rather as an instrument for designing buildings. It can't be imposed by laws or rules, not only because it must be a cultural approach, but because there is a lack in defining a clear map of sustainable requirements.

The present research suggests a list of requirements usable to evaluate the sustainable quality. To recognise such requirements the research starts from the analysis of the main assessment methods listed by the ISO TC59[3]: GBTool, BREEAM, LEED, CASBEE-J.

The list has been developed corresponding to the scheme of technological units and technical elements, which make up the building technological system.

The following schema summarizes the demands and requirements recognized in the research:

Tab. 1 In this schema of synthesis, demands and requirements are specific for the technological system of the building and they are set up starting from the most frequent scores obtained using GBTool, BREEAM, LEED and CASBEE-J assessment methods

Demands	SUSTAINABILITY Requirements
CONSIDERATE CONSTRUCTORS	Planned measures to minimize construction accidents
	Planned measures to minimize construction time
	Prefabrication/industrialization
	Fast transport and packing
	Reduction of the waste production during the construction and deconstruction phases
	Reduction of the use of energy and raw materials
	Simple and fast construction/deconstruction
	Waste management on site
NEIGHBOURHOODS	Use of locally produced materials
	Use of local techniques and building systems
USE OF SUSTAINABLE MATERIALS	Use of environmental friendly materials
	Use of no-toxic materials
	Use of renewable materials
	Use of materials that have less impact on the environment (labelled materials)
	Use of materials with the CE label
ENERGY	Reduction of the energetic consumption in the phase of building construction
	Thermal conductivity

[2] UNI is the Italian Organization for Standardization.

[3] ISO TC59 is trying to create an international standard for environmental declarations for building products. TC59/SC3 is responsible for standardization work of environmental assessment tools at building level. It involves GBTool, BREEAM, LEED, CASBEE-J, ENVEST, Ecoprofile, Eco-effect, Eco-Quantum, Green Calc, mmg.

	Interposing material that prevents the loss of heat
DURABILITY	Reliability
	Controllability
	Maintenance
	Reparability
	Replace ability
ADAPTABILITY	Constructive systems adaptable to environment changeability
	Adaptability constraints imposed by new demands of users
REUSE/RECYCLE	Do not use toxic materials
	Design for re-use or recycling
	Homogeneity of components
	Dry construction
	Design for disassembly
	Planned use of recycled materials
	Planned re-use of salvaged materials
	Biodegradable materials
HEALTH AND WELLBEING	Comfort in day lighting and illumination
	Design features to maintain acceptable air temperature and relative humidity
	No toxic emissions
	Ensure the provision of sound insulation and reduce the likelihood of noise complaints
	Selection of materials with minimal off-gassing of pollutants
ECONOMIC ASPECTS	Life Cycle Cost
	Planned measures to minimize construction cost
	measures planned for minimization of operating and maintenance cost

4 Conclusions

The present research suggests what Building Quality [BQ] could be in order to make a better interpretation of the relationship between building and environment. BQ is the correct equivalence between the building and the purpose for which it has been built. BQ can be expressed in terms of: $BQ = P / R \geq 1$. Such a formula evaluates the level of quality as the ratio of performance[4] [P] to requirement[5] [R]: in this way plurality of demands is transformed in measurable requirements that can be compared with the behaving of the building. BQ could be attested while value and quantity of performances are nothing more than requirements (Manfron, 1995).

The aim of this part is to analyse the "Sustainable Quality" making reference to the Total Quality Management system[6] [TQM] and to the Plan, Do, Check, Act cycle[7]

[4] Performance is the behaviour of the building and/or of its parts under the condition of use (UNI 10838:1999).
[5] Requirement is the transformation of a need in an analogous list of goals that are aimed at defining users' satisfaction for a building and/or of its parts under the condition of use (UNI 10838:1999).
[6] TQM is a contractor performance development model that promotes entrepreneurship, innovation, sustainability and global competitiveness of contractors. The TQM philosophy is based on several principles. Amongst them there are a strong leadership, a long-term business perspective, a care for staff and communities, a balanced, holistic approach to business management.
[7] PDCA means *1- Plan: establish the objectives and processes necessary to deliver results in accordance with the organization's environmental policy. 2- Do: implement the processes. 3- Check: monitor and measure processes against environmental policy, objectives, targets, legal and other requirements, and report the results. 4- Act: take actions to continually improve performance of the environmental management system.* (UNI EN ISO 14001/2004)

[PDCA]. In this topic, Quality Control, Quality of the Process and Certification become central concepts. These concepts which were originally oriented to increase productivity have been transferred to the sustainable challenge to improve the quality of the building process and the quality of the environment as well. The redefinition of ELCC is based on the evaluation of environmental loads: an industrial process needs fuel and materials input with a corresponding waste and heat output (Odum, 1997). This concept is based on the evaluation of energy, also said “energy memory”: all the energy used in a process should be thought as embodied in the products of the process. The ELCC formula adds loads caused by all the steps considered in the Extended Life Cycle analysis of a product or a building. The formula values all the aspects of the loads, also the economic and the social ones. The formula does’t analyse only the loads of the industrial process, it is the opposite of the current practice in the Life Cycle Analysis [LCA][8].

So the present paper proposes a cost/benefit analysis of the activities relating to the ELCC of the industrial and building process (**Fig. 3**). According to such concepts, the paper assigns a separate evaluation of Quality and Load. It gives an evaluation of Environmental Efficiency [EE] according to the following formula: $EE = Q/L \geq 1$ where:

[Q] is the environmental quality and performance of the building and its evaluation is based on the improvement in living wellness for the building users, within the hypothetical enclosed space (private property),

[L] is the building environmental load and its evaluation is based on the negative aspects of environmental impact, which go beyond the hypothetical enclosed space to the outside (public property).

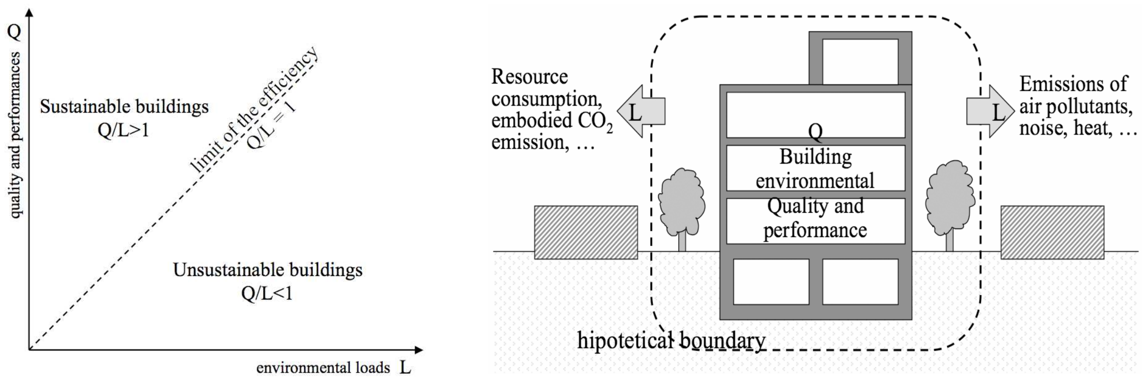

Fig. 3 The environmental efficiency is the balance between the performance (of a material, of a building constructive system, of a building) and the ecosystem. The evaluation of environmental efficiency should be represented on the graph by plotting L on the x-axis and Q on the y-axis. The graph gives a simple and clear presentation of building performance assessment results.

In such a way the sustainability of constructions is linked to the performances which building guarantees to users of the building (main users), to users of the place situated next to or very near the building and to all the people who live in a setting changed by the behave of the previous two “types of users”. The concept of Environmental Efficiency involes:

- the correct linkage of the material with the product,

[8] Life Cycle Analysis [LCA] is the technique for assessing the environmental aspects and impacts associated with a product, or a service, in a life cycle perspective. Environmental impacts refer to the demand for natural resources, emissions to air, water, soil and solid waste. The life cycle consists of the processes and transport involved during raw materials extraction, refining of raw materials, manufacture of the product, use of the product and waste management.

- the correct linkage of the product with the system in which it is used,
- the correct linkage of the building with the environment in which it is designed.

So the Environmental Efficiency should be a strategy to analyse performances of the technological system and performances of the building.

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