Improving the Design of a Residential Building Using the Portuguese Rating System SBTool^{PT}

Luis Bragança
University of Minho, Guimarães, Portugal
braganca@civil.uminho.pt

Ricardo Mateus
University of Minho, Guimarães, Portugal
ricardomateus@civil.uminho.pt

ABSTRACT: Construction affects all dimensions of sustainability (environment, society and economy) and therefore a sustainable building design has to cope with tens of criteria, most of them interrelated and partly contradictory. There are a great number of indicators and assessment tools that have been developed recently in order to evaluate the sustainability of buildings and urban settlements. Most of these tools are based on national standards, building codes and local methods of construction. Sustainable design of construction is only possible through a real methodological work. Sustainability assessment tools play an important role at this level, since they convert the sustainability issues into tangible goals while are used to collect and communicate the results of a sustainability assessment. This paper will present the role of the Portuguese Sustainability Rating System SBTool^{PT} in promoting the sustainability of residential buildings.

1 INTRODUCTION

In Portugal, most of the impacts of the built environment in the sustainable development are related to the residential sector (Mateus, 2009). At the environmental level this sector is directly and indirectly related to the consumption of a great amount of natural resources (energy, water, mineral, wood, etc.) and to the production of a significant quantity of residues. For example, although Portugal has a mild climate, residential sector accounts for about 17% of the total national energy consumption (DGGE, 2005). Additionally, it uses a considerable amount of water resources, about 132 l/inhabitant/day of potable water, being a significant part of this capitation used in toilets (INAG, 2005). At the socioeconomic level and compared to other sectors, buildings is the most important sector, not only because about 10% of the global economy is related with its construction and operation, but also because it significantly influences the quality of life and heath of its inhabitants: in the developed countries, people are inside buildings in about 80% to 90% of the period of their life (Roodman and Lessen, 1995). Nevertheless, some studies in Portugal showed that most buildings are not sustainable in terms of operating and maintenance costs and do not provide a comfortable and healthy indoor environment for their occupants (Mateus, 2009). For example, the reality shows that 23% of the Portuguese residential buildings need to be repaired and their owners do not have the necessary income for the necessary investment (INE, 2001).

Due to the increasing awareness about the consequence of the contemporary model of development in the climate change and to the growing international movement toward high-performance/sustainable buildings, more and more the current paradigm of building is changing. This is changing both the nature of the built environment as well the actual way of designing and constructing a facility. This new approach is different from the actual practice by the selection of project teams members based on their eco-efficient and sustainable building expertise; increased collaboration among the project team members and other stakeholders; more focus on global building performance that on building systems; the heavy emphasis placed on environmental protection during the whole life-cycle of a building; careful consideration of worker health and occupant health and comfort through all phases; scrutiny of all decision for their resource and life-cycle implications; the added requirement of building commissioning; and the emphasis placed on reducing construction and demolition waste (Kibert, 2005).

Although there are several definitions for a sustainable building, generally speaking, it uses resources like energy, water, land, materials in a much more efficient way than conventional buildings. These buildings are also designed and used in order to produce healthier and more productive living, work and living environments, from the use of natural light and improved indoor environmental quality (Syphers et al, 2003). Therefore, sustainable building aims the proper balance between the three dimensions of the sustainable development: Environment, Society and Economy.

Archiving sustainability at the building sector is only possible through a real methodological work. In order to be feasible this work should be carried out during the preliminary phases of design. At this level sustainability assessment tools are playing an important role, since they gather and report information for decision-making during the different phases of construction, design and use of a building. The sustainability scores or profiles based on indicators result from a process in which the relevant phenomena are identified, analyzed and valued.

Building sustainability assessments based on a life-cycle approach can produce important long-term benefits for both building owners and occupants (Hilkmat, 2009), namely: helping to minimize environmental impacts; solving existing building problems; creating healthier, more comfortable and more productive indoor spaces, and reducing building operation and maintenance costs. Life-cycle analysis considers all the inputs and outputs of acquiring, owning, and disposing of a building system. This approach is particularly useful when project alternatives, which fulfil the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared in order to select the one that maximizes net savings (Hilkmat, 2009).

This paper aims to highlight the contribution of the sustainability assessment tools for the sustainable building design. Moreover it will present the role of the Portuguese Sustainability Assessment Tool (SBTool^{PT}) in promoting the design of a sustainable affordable residential building by presenting a case study.

2 BRIEF PRESENTATION OF THE SBTool^{PT} METHODOLOGY

2.1 *Framework*

The Sustainable Building Tool - SBTool is a building sustainability assessment method that result from the collaborative work of several countries, since 1996 and it was promoted by the International Initiative for a Sustainable Built Environment (iiSBE). This international involvement supported its distinction among the others methodologies, since SBTool was designed to allow users to reflect different priorities and to adapt it to the regional's environmental, socio-cultural, economy and technological contexts.

The Portuguese version of SBTool - SBTool^{PT} - was developed by the Portuguese chapter of iiSBE, with the support of University of Minho and the private company EcoChoice. In this methodology all the three dimensions of the sustainable development are considered and the final rate of a building depends on the comparison of its performance with two benchmarks: conventional practice and best practice. This methodology has a specific module for each type of building and in this paper the module to assess residential buildings (SBTool^{PT} – H) was used.

The physical boundary of this methodology includes the building, its foundations and the external works in the building site. Issues as the urban impact in the surroundings, the construction of communication, energy and transport networks are excluded. Regarding the time boundary, it includes the whole life cycle, from cradle to grave.

Table 1 lists the categories (global indicators) and indicators that are used in the methodology to access residential buildings. It has a total of nine sustainability categories (summarizes the building performance at the level of some key-sustainability aspects) and 25 sustainability indicators within the three sustainability dimensions.

The methodology is supported by an evaluation guide and its framework includes (Figure 1):

i) Quantification of performance of the building at the level of each indicator presented in a evaluation guide;
ii) Normalization and aggregation of parameters;
iii) Sustainable score calculation and global assessment.

In order to facilitate the interpretation of the results of this study the main steps of the SBTool^{PT} approach will be presented in the next sections.

Table 1. List of categories and sustainability indicators of the SBTool^{PT} methodology.

Dimension	Categories	Sustainability indicators
Environment	C1 – Climate change and outdoor air quality	P1 – Construction materials' embodied environmental impact
	C2 – Land use and biodiversity	P2 - Urban density P3 – Water permeability of the development P4 - Use of pre-developed land P5 – Use of local flora P6 – Heat-island effect
	C3 – Energy efficiency	P7 – Primary energy P8 – In-situ energy production from renewable
	C4 – Materials and waste management	P9 – Materials and products reused P10 – Use of materials with recycled contend P11 – Use of certified organic materials P12 – Use of cement substitutes in concrete P13 – Waste management during operation
	C5 – Water efficiency	P14 – Fresh water consumption P15 – Reuse of grey and rainwater
Society	C6 – Occupant's health and comfort	P16 – Natural ventilation efficiency P17 – Toxicity of finishing P18 – Thermal comfort P19 – Lighting comfort P20 – Acoustic comfort
	C7 – Accessibilities	P21 – Accessibility to public transportations P22 – Accessibility to urban amenities
	C8 – Awareness and education for sustainability	P23 – Education of occupants
Economy	C9 – Life-cycle costs	P24 – Capital cost P25 – Operation cost

2.2 *Assessment procedure*

i) Quantification

The evaluation guide presents the methodologies that should be used by the assessor in order to quantify the performance of the building at level of each sustainability indicator.

At the level of the environmental parameters, SBTool^{PT} uses the same environmental categories that are declared in the Environmental Product Declarations. At the moment, there are limitations with this approach due to the small number of available EPD. Therefore the methodology integrates a Life-cycle Assessment (LCA) database that covers many of the building technologies conventionally used in buildings (Bragança et al, 2008b). Nevertheless, since the LCA database did not cover all building technologies used in the assessed building, in this study was necessary to use one external LCA tool (SimaPro).

At the level of the societal performance, the evaluation guide presents the analytical methods that should be used to quantify the parameters.

The economical performance is based in the market value of the dwellings and in their operation costs (costs related to water and energy consumption).

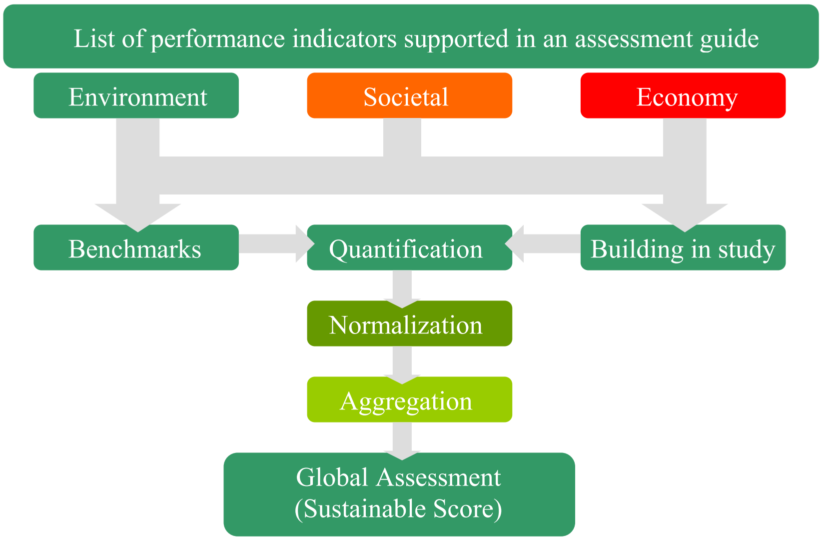

Figure 1. Framework of the SBTool^{PT} methodology.

ii) Normalization and aggregation of parameters

The objective of the normalization is to avoid the scale effects in the aggregation of parameters inside each indicator and to solve the problem that some parameters are of the type "higher is better" and others "lower is better".

The used normalization process allows comparing the performance of the building under assessment with two benchmarks: best practice and conventional. This process in addition to turning dimensionless the value of the parameters considered in the assessment, converts the values between best and conventional practices into a scale bounded between 0 (worst value) and 1 (best value). In order to facilitate the interpretation of results, the normalized values of each parameter are converted in a graded scale, as presented in Figure 2.

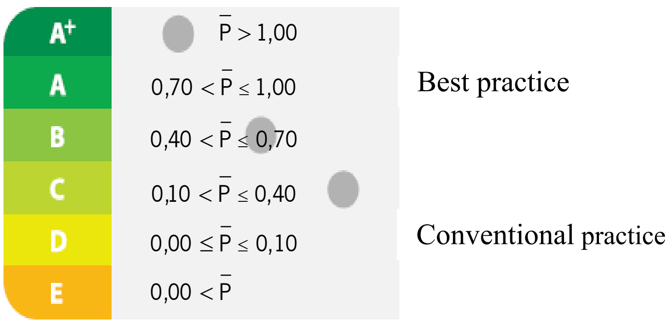

Figure 2. Conversion of the quantitative normalized parameters into a qualitative graded scale.

As an example, Figure 3 presents the differences between the qualitative level A+ and the qualitative level D when normalizing the parameter P14 - Fresh water consumption. In this case, the water consumption of an A+ building is more than 50% lower than a conventional one.

The aggregation consists on a weighted average of the indicators into categories and the categories into dimensions in order to obtain three single indicators. These three values are obtained using the equation (1) and the final result gives the performance of the building at the level of each sustainability dimension.

$$I_j = \sum_{i=1}^{n} w_i . \overline{P_i} \tag{1}$$

The indicator I_j is the result of the weighting average of all the normalized parameters $\overline{P_i}$. w_i is the weight of the i^{th} parameter. The sum of all weights must be equal to 1. The weights of the environmental indicators are based in a study from the US Environmental Protection Agency's

Science Advisory Board study (TRACI) and the societal weights are base on studies that were carried out in the Portuguese population (Bragança *et al*, 2008a).

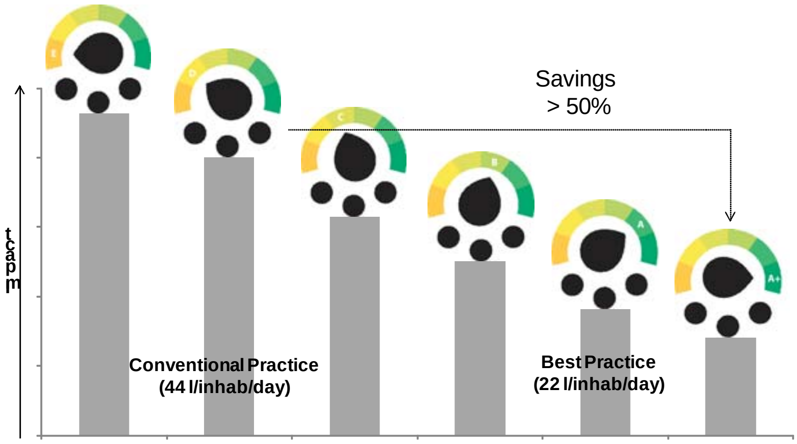

Figure 3. Benefits of an A^+ building (example for the parameter P14 – Water consumption).

iii) Global assessment and labelling

The last step of the methodology is to calculate the sustainable score (SS). The SS is a single index that represents the global sustainability performance of the building, and it is evaluated using the equation (2).

$$SS = w_E x I_E + W_S x I_S + W_C x I_C \quad (2)$$

Where, *SS* is the sustainability score, I_i is the performance at the level of the dimension *i* and w_j is the weight of the dimension j^{th}. Table 2 presents the weight of each sustainable solution in the assessment of the global performance.

Table 2. Weight of each sustainability dimension on the methodology $SBTool^{PT}$ – H.

Dimension	Weight (%)
Environmental	40
Societal	30
Economy	30

At the end, the performance of a building is measured against each category, sustainable dimension and global score (sustainable score) and is ranked on a qualitative scale bounded from A+ to E.

3 PRESENTATION OF THE CASE STUDY

The case-study is a multifamily cooperative housing building block that is the Portuguese pilot - project of the European Program "SHE: Sustainable Housing in Europe" (http://www.she.coop).

The Portuguese pilot project was the second phase of the Ponte da Pedra housing state that was built in the municipality of Matosinhos, Northern Portugal (Figure 1). It is a multifamily social housing project, which promoter is NORBICETA - União de Cooperativas de Habitação, U.C.R.L. This project has two building blocks, a footprint of $3105m^2$, a total gross area of $14.852m^2$ and 101 dwellings. It was co-sponsored by the project SHE and by the National Housing Institute (INH) and had the support of the FENACHE (national federation of social housing cooperatives), FEUP (Faculty of Engineering of the University of Porto) and UM (University of Minho). This project aimed to demonstrate the real feasibility of sustainable housing in Portugal and it succeed since it proved the practical feasibility of building a residential building with lower environmental impacts, higher comfort and lower life-cycle costs, when compared to a conventional one.

During the design phase, the project team adopted a series of priorities in order to create a sustainable affordable building block. The most important priorities were:

i) To use pre-developed land: this housing state was built in an area that was occupied by decayed industrial buildings (Figures 4 and 5). By contributing to the regeneration of the land and to the improvement of around urban area, this project had a positive local impact. On the other hand, due to the fact of not using new land it will contribute for the maintenance of local biodiversity;
ii) Energy efficiency: the primary energy consumption is about 25% of the local's conventional practice; it uses efficient lighting in public spaces; and solar collectors for hot water (Figure 6);
iii) Water efficiency: building is equipped with a rainwater harvesting system that guarantees at about 100% of the water supply for green areas and toilets (Figure 7); and it is equipped with low water flow devices (Figures 8 and 9);
iv) Improvement of the indoor air quality: all window frames are equipped with ventilation grids (Figure 10);
v) Management of household waste: all kitchens are equipped with containers for each of the four types of household solid waste (Figure 11); the outside containers are located nearby the building's entrance;
vi) Controlled costs: compared to the first phase of the Ponte da Pedra housing state (that have the same type of architecture but uses the conventional building technologies) the construction cost was about 9% higher. The promoter assumed part of this higher capital cost and the dwellings were sold at a price 5% higher than the first phase. According to the promoter, the turn-off of this higher capital cost will about 5 to 6 years. Nevertheless, dwellings were sold at an average price that was 20% below the local's average market practice.

Figure 4. General exterior view of the building blocks.

Figure 5. Aspect of the local before the intervention.

Figure 6. Hot water solar collectors (thermodynamic system).

Figure 7. Rainwater tank (construction phase).

Figure 8. Low flow showers.

Figure 9. Double flush toilets (6/3 l).

Figure 10. Ventilation grids on window frames.

Figure 11. Containers for solid waste separation.

4 RESULTS

4.1 *Performance at the level of each sustainability category and dimension*

Table 3 presents the values obtained in the assessment of the performance at the level of each sustainability category and dimension. Analysing the results it is possible to verify that all priorities adopted by the project team (described above) were recognised by the SBTool^{PT} methodology and therefore almost all categories (except one) have a performance grade above the conventional practice. The analysed building is only worst than the conventional practice in the category C1 “Climate change and outdoor air quality”. This situation results from the fact that the building uses solid clay bricks on the exterior cladding (one material with greater embodied environmental impacts than the conventionally used materials). In compensation, building is above the best practice’s benchmarks at the level of three categories: C5 “Water efficiency”, C8 “Awareness and education for sustainability”, C9 “Life-cycle costs”. The good performance at the level of the water efficiency is mainly influenced by the implementation of the rainwater harvesting system; the good performance on category C8 is because all dwelling have a complete user manual that guides the inhabitants for the sustainable management of it; and the good economy performance is quite dependable on the lower market price of the dwellings (20% lower than average local’s market practice).

Table 3. Results obtained from the SBTool^{PT} – H for each sustainability category and dimension.

Dimension	Category	Performance (normalized value)	Performance (qualitative value)	Weight (%)	Dimension Performance (I_A)
Environmental	C1	-0,20	E	13	B
	C2	0,56	B	20	
	C3	0,72	A	32	
	C4	0,10	D	29	
	C5	1,03	A+	6	
Societal	C6	0,60	B	60	B
	C7	0,74	A	30	
	C8	1,13	A+	10	
Economy	C9	1,20	A+	100	A^+

4.2 *Global assessment*

Table 5 resumes the obtained results at the level of each dimension of the sustainable development and the global performance (Sustainable Score). According to the results this building has an A grade, which means that it is considered the best practice in the Portuguese context. Figure 12 shows the SBTool^{PT}’s sustainability label according to the presented results.

Table 5: Results obtained from the SBTool^{PT} – H for the global assessment.

Dimension	Performance (normalized value)	Performance (qualitative value)	Weight (%)	Sustainable Score (SS)
Environmental	0,41	B	40	A
Societal	0,69	B	30	
Economy	1,20	A^+	30	

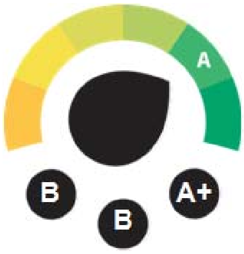

Figure 12. Ponte da Pedra real state’s SBTool^{PT} label.

5 CONCLUSIONS

The sustainable design, construction and use of buildings are based on the best trade-off between environmental pressure (relating to environmental impacts), social aspects (relating to users' comfort and other social benefits) and economic aspects (relating to life-cycle costs). Sustainable design strives for greater compatibility between the artificial and the natural environments without compromising the functional requirements of the buildings and the associated costs.

This paper presented the contribution of the SBTool^{PT} in promoting the sustainability of existing, new and renovated residential buildings in urban areas, specifically in the Portuguese context. The definition of an objective list of indicators and related parameters is a fundamental tool for designers which help the implementation of the sustainable construction goals since the preliminary phases of a design.

The presented case-study showed that even with little increase on capital costs (9%) it is possible to design a building with a good level of sustainability, even in cooperative housing (dwellings' price was 20% lower than the local conventional prices). Being this pilot-project nationally and internationally recognized has a good sustainability practice it is possible to conclude that the SBTool^{PT} – H is well adapted to the Portuguese's environmental, societal and economy contexts.

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