Building Sustainability Assessment: System SBTool$^{PT®}$

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

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

ABSTRACT: The multidimensional concept of sustainable building is often related solely to environmental indicators although the social, economic and cultural indicators are of substantial importance. The weight of various indicators depends on the context of a building project and further, interpretation of the assessment results depends on the sustainability strategies of the society. The recent Portuguese research on the applicability of assessment methods developed abroad shows, that modifications are necessary and local factors are crucial for each indicator as such but also for their relative meaning. Assessment of sustainability of buildings involves several interrelated and partly contradictory aspects. The different methods give insights to basics and cause-consequences instead of clear-cut results. For this reason, the use of assessment results (scores, indexes and profiles) in decision-making presupposes transparency and clarity. Based on the case studies of building sustainability assessment using various tools, the environmental indicators were shown to be often of lesser importance than the other, soft ones.

This paper aims to present a novel approach to develop building sustainability assessment and rating and contributes to the evolution of generic methodology and international understanding by introducing an approach to take the different dimensions of sustainability into account. This methodology is based in the adaptation of the international Sustainable Building Tool (SBTool) to the Portuguese's environmental, societal and economy contexts. The scope of the methodology that is going to be presented (SBTool$^{PT®}$) is to assess the sustainability of existing, new and renovated buildings in the urban areas and especially in the Portuguese context. This new methodology is intended to foster the awareness of the Portuguese construction market stakeholders and to allow adequate policy implementation on sustainable construction.

1 INTRODUCTION

In the construction and real estate sector, the sustainability issues are related to those with global features but as well to those with local and sectorial features. The sector has a great influence on economies and societies, and thus it is linked in global environmental sustainability indexes, like e.g. the ESI scores by Universities of Yale and Columbia that benchmarks the ability of nations to protect the environment worldwide (2005). The Agenda 21 on sustainable construction (1999) emphasized the significance to proceed with related non-technical issues, when improvement strategies are to be successfully implemented. The fundamental differences between the dimensions have been described by Ronchi, Federico and Musmeci (2002) in a way that "the quality of life is recognised as the non-physical and non-ecosystem counterpart of any suitable model of sustainable development".

A building project can be regarded as sustainable only when all the various dimensions of sustainability –environmental, economic, social and cultural ones - are dealt with. The various sustainability issues are interwoven, and the interaction of a building and its surroundings is also important. They are in common those which cope with reducing use of non-renewable materials and water as well as production of emissions, waste and pollutants. The following goals can be found in several agendas: optimization of site potential, preservation of regional and cultural identity, minimization of energy consumption, protection and conservation of water resources, use of environmentally friendly materials and products, healthy and convenient indoor climate and optimized operational and maintenance practices.

A variety of sustainability assessment tools is available on the construction market, and they are widely used as a basis for environmental product declarations. The majority of tools for building level assessment has then been developed by summing up results of building materials and components to a building. There are LCA-based tools available that are especially developed to address the building as whole, like e.g. Eco-Quantum (Netherlands), EcoEffect (Sweden), ENVEST (U.K.), BEES (U.S.), ATHENA (Canada) and LCA House (Finland). A comparison of contextual and methodological aspects of tools has been made e.g. by Forsberg and Malmborg (Forsberg, 2004).

Three major building rating and certification systems are providing the basis for the other applications throughout the world. They are Building Research Establishment Environmental Assessment Method BREEAM, developed in U.K.; Sustainable Building Challenge Framework SBTool, developed by the collaborative work of the International Initiative for a Sustainable Built Environment (iiSBE); and Leadership in Energy and Environmental design LEED, developed in U.S.A.

In the Sustainable Building Tool (SBTool) the approach is to weight different criteria, considering weighting factors that are fixed at national level. Each "score" results from the comparison between the studied building and national reference. This scheme allows an international comparison of buildings from different countries. Other tools, like for instance BREEAM and LEED, are based upon credits. The maximum number of credits available for each indicator it is related to its weight in the overall score, that is expressed by a rating (e.g. from Pass to Excellent in BREEAM).

This paper presents a novel approach to develop building sustainability assessment and rating. The main objective of a systematic methodology is to support building design that achieves the most appropriate balance between the different sustainability dimensions, and that is at the same time practical, transparent and flexible enough to be easily adapted to different kinds of buildings and to technology. This new approach, Sustainable Building Tool for Portugal ($SBTool^{PT®}$), is adapted to the Portuguese construction context, and as first step is developed to support the sustainable design and the sustainability assessment of new and renovated residential buildings $SBTool^{PT®}$ – H).

2 SCOPE AND OBJECTIVE OF THIS NEW METHODOLOGY

The scope of the research work performed in the iiSBE Portugal, was to develop and propose a generic methodology to assess the sustainability of existing, new and renovated buildings in the urban areas and especially in the Portuguese context. It is intended to foster the awareness of the Portuguese construction market stakeholders and to allow adequate policy implementation on sustainable construction.

As a first step, a methodology to assess the sustainability of residential buildings has been developed. Reasoning for this priority is due to the fact that most of the impacts related to the construction sector are related to the housing sector. The acronym of the methodology is $SBTool^{PT®}$ - H (Sustainable Building Tool for Sustainable Housing in Portugal).

The following priorities were approached in the development of the $SBTool^{PT®}$:

- To develop a list of parameters wide enough to be meaningful and to comprise the most relevant building impacts and at the same time limited enough to be practical;
- To develop a building-level assessment method, based upon the state-of-the-art of methodologies and considering ongoing standardization;
- To be balanced between all different dimensions of sustainable development (environment, societal and economics);
- To limit or exclude the subjective and/or qualitative criteria that is hard to validate (e.g. aesthetics and technical innovation);

- To improved reliability through the use of accepted LCA methods for environmental performance;
- To have an assessment output and certification label that is easy for building users to interpret and understand but is also one which clients and designers can work with.

As a result of the research work, the $SBTool^{PT®}$ is based in the SBTool approach and is harmonized with the CEN/TC350 draft standards "Sustainability of Construction Works – Assessment of Environmental Performance of Buildings" (CEN, 2009). This methodology allows future rating and labelling of buildings, in analogy with the Energy Performance of Buildings Directive.

Although the interaction between a building and its surroundings is of importance for sustainability (e.g. energy performance, social indicators) it was decided to exclude this aspect. The main reason was that in an urban environment, the decisions concerning the surroundings and networks of a site are mostly made by the local and regional authorities. However, some publications have concluded that restricted scales of study (corresponding for a single building for example) are too limited to take into account sustainable development objectives correctly (Bussemey-Buhe, 1997).

3 FRAMEWORK OF THE $SBTool^{PT®}$

3.1 *Categories, Indicators and Parameters*

The Portuguese version of SBTool - $SBTool^{PT®}$ - was developed by the Portuguese chapter of iiSBE, with the support of University of Minho and the 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) is presented.

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 is structures in the following steps (Figure 1):

1. Quantification of performance of the building at the level of each indicator presented in a evaluation guide;
2. Normalization and aggregation of parameters;
3. Sustainable score calculation and global assessment.
4. 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.

3.2 *Quantification of Parameters*

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

$SBTool^{PT®}$ 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, authors decided to develop a Life-cycle Assessment (LCA) database that covers many of the building technologies conventionally used in buildings. This database covers the most used building technologies for each building element (walls, floors, windows, doors, etc.) and it is built-in in the $SBTool^{PT®}$ methodology. The database covers the parameters presented in Table 2. The values of the parameters are presented for two life-cycle stages: "cradle to gate" and "demolition/disposal" (Bragança, 2008).

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 renewables
	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 costs
		P25 – Operation costs

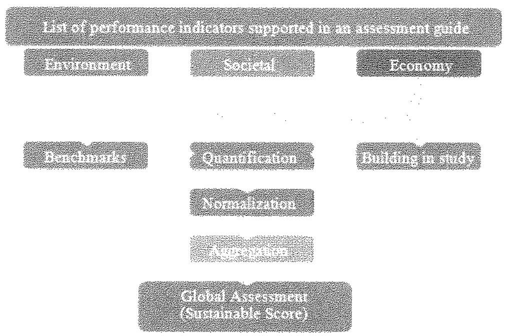

Figure 1. Framework of the methodology SBTool$^{PT®}$.

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).

Table 2. Parameters declared in the built-in LCA database for building technologies

Parameter	Unit/declared unit	Source
Depletion of abiotic resources	[kg Sb equiv.]	CML 2 baseline 2000
Global warming potential (GWP)	[Kg CO2 equiv.]	IPCC 2001 GWP 100a
Destruction of atmospheric ozone (ODP)	[KgCFC-11 equiv.]	CML 2 baseline 2000
Acidification potential (AP)	[Kg SO2 equiv.]	CML 2 baseline 2000
Eutrophication potential (NP)	[Kg PO4 equiv.]	CML 2 baseline 2000
Photochemical Ozone Creation (POCP)	[Kg C2H4 equiv.]	CML 2 baseline 2000
Non-renewable primary energy	[MJ equiv.]	Cumulative Energy Demand
Renewable primary energy	[MJ equiv.]	Cumulative Energy Demand

3.3 *Normalization, Aggregation and Weights*

The objective of the normalization of parameters 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". Normalization is done using the Diaz-Balteiro et al. Equation 1 (Diaz-Balteiro, 2004).

$$\overline{P_i} = \frac{P_i - P_{*i}}{P_i^* - P_{*i}} \forall_i \qquad (1)$$

In this equation, Pi is the value of ith parameter. P*i and P*i are the best and worst value of the ith sustainable parameter. The best value of a parameter represents the best practice available and the worst value represents the standard practice or the minimum legal requirement.

Normalization in addition to turning dimensionless the value of the parameters considered in the assessment, converts the values between best and conventional/reference practices into a scale bounded between 0 (worst value) and 1 (best value). Excellent practices will have a score above 1 and performances bellow the reference will have a negative normalized value. This equation is valid for both situations: "higher is better" and "lower is better".

For example, the normalization of the primary energy used for heating (hot water heating included) is done as presented in Table 3 and Equation 2.

In order to facilitate the interpretation of results, the normalized values of each parameter are converted in a graded scale, as presented in Table 4.

Although building sustainability assessment across different fields and involves the use of numerous indicators and tens of parameters, a long list of parameters with its associated values won't be useful to assess a solution. The best way is to combine parameters with each other inside each dimension in order to obtain the performance of the solution in each indicator (Allard, 2004).

Table 3. Parameters declared in the built-in LCA database for building technologies

Parameter	Primary energy used for heating (hot water heating included)
Notation	Eh
Unit	kWh/m²/year
Value	100
Reference value	140
Best practice	35

$$\overline{Eh} = \frac{Eh - Eh_*}{Eh^* - Eh_*} = \frac{100 - 140}{35 - 140} = 0{,}38 \qquad (2)$$

The methodology uses a complete aggregation method for each indicator, according to Equation 3.

$$I_j = \sum_{i=1}^{n} w_i \cdot \overline{P_i} \qquad (3)$$

The indicator Ij is the result of the weighting average of all the normalized parameters. $\overline{P}_i$ wi is the weight of the ith parameter. The sum of all weights must be equal to 1.

In the definition of the environmental indicators' weights the methodology uses 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, 2008).

Table 4. Parameters declared in the built-in LCA database for building technologies

Grade	Values
A+ (Above best practice)	$\overline{P}_i > 1,00$
A	$0,90 < \overline{P}_i \leq 1,00$
B	$0,70 < \overline{P}_i \leq 0,90$
C	$0,50 < \overline{P}_i \leq 0,70$
D	$0,30 < \overline{P}_i \leq 0,50$
E	$0,10 < \overline{P}_i \leq 0,30$
F (Reference practice)	$0,00 < \overline{P}_i \leq 0,10$
G (Bellow reference)	$\overline{P}_i \leq 0,00$

3.4 *Global assessment of a project and visualization of the results*

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 (4).

$$SS = w_E x I_E + W_S x I_S + W_C x I_C \quad (4)$$

Where, SS is the sustainability score, Ij is the performance at the level of the dimension j and w_j is the weight of the dimension j^{th}.

Table 5 presents the weight of each sustainable solution in the assessment of the global performance.

Table 5. Weight of each sustainability dimension on the methodology SBTool$^{PT®}$ – H.

Dimension	Weight (%)
Environmental	40
Societal	30
Economy	30

Normally, the majority of the stakeholders would like to see a single, graded scale measure representing the overall building score. Such score should be easily for building occupants to understand and interpret but also one which clients, designers and other stakeholders can work with.

Having it in mind, in SBTool$^{PT®}$ the overall performance of a building is represented by a single score in a graded scale. The methodology adopted a similar approach to the one used in the existing labelling schemes such as the EU energy labelling scheme for white goods and the European Display^{TM} Campaign posters. However, due to the possible compensation between categories, the global performance of a building is not communicated using only the overall score. This way, the performance of a building is measured against each category, sustainable dimension and global score (sustainable score) and will be ranked on a scale from A+ to E. Figures 2 and 3 represents the outputs of the SBTool$^{PT®}$ methodology for a hypothetical case study.

From the outputs of this building sustainability assessment method it is possible to monitor and compare the performance of the solution in study with the reference solution (D grade). Nearest to the grade A+ is the performance of the solution, more sustainable it is. If the solution has a grade E in one parameter or category it means that special attention should be given to that issue, since it has a worst performance that the reference solution at that level.

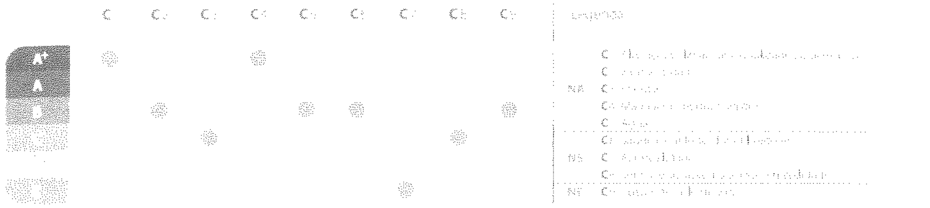

Figure 2. SBTool$^{PT®}$ output for a hypothetical building - performance of the solution presented at the level of the different categories.

Figure 3 SBTool$^{PT®}$ output for a hypothetical building - performance of the solution presented at the level of the three sustainable dimensions and sustainable score.

4 CONCLUSIONS

Sustainable design, construction and use of buildings are based on the evaluation of the environmental pressure (related to the environmental impacts), social aspects (related to the users comfort and other social benefits) and economic aspects (related to the life-cycle costs). The sustainable design searches for higher compatibility between the artificial and the natural environments without compromising the functional requirements of the buildings and the associated costs.

Despite of numerous studies about the building sustainability assessment, there is a lack of a commonly accepted methodology to assist the architects and engineers in the design, construction and refurbishing stages of a building. Nevertheless, in spite of the limitations of different methods, the widespread of assessment methods is having several direct and indirect impacts in the sustainable building design. The actual LCA methods and building rating tools are having a positive contribution in the fulfilment of sustainable developing aims.

Many countries are either having or being in the process of developing domestic assessment methods, and therefore the international exchanges and coordination is increasingly needed. This paper contributes to the evolution of generic methodology and international understanding by introducing an approach to take the traditions and social aspects into account.

The SBTool$^{PT®}$ methodology supports steps toward the sustainable design and construction, through the definition of a list of objectives that are easily understandable by all intervenient in construction market and compatible with the Portuguese construction technology background.

REFERENCES

Kibert, Charles J. 2005. Sustainable construction: green building design and delivery, *John Wiley & Sons*, New Jersey, United States of America.

Forsberg A. & Malmborg von F. 2004. Tools for environmental assessment of the built environment, *Building and Environment 39(2004)* Issue 2, pages 223-228.

prEN 15643-2. Sustainability of Construction Works — Integrated assessment of building performance — part 2: framework for the assessment of environmental performance. *CEN/TC 350/ Task Group "framework" n 049*. European Committee of Standardization (CEN).

Bussemey-Buhe C. 1997. Dévelopment d'une méthode de conception environmental des bâtiments prenant en compte l'environnement de proximité. *Ph. D. Thesis, Université de Savoie*, Savoie, France.

Bragança, L.; Mateus, R. 2008. New Approach to Environmental Life-Cyle Analysis in Sustainability Rating Systems. *Proceedings of the international conference "CINCOS'08: congresso de inovação na construção sustentável"*. Curia, Portugal: October, ISBN 978-989-95978-0-8. p. 331-345.

Diaz-Balteiro L. & Romero C. 2004. In search of a natural systems sustainability index, *Ecological Economics, 49,* pp 401-405.

Allard, F., Chéqui, F., Wurtz, E. & Mora, L. 2004. A Methodology To Assess The Sustainability Of Rehabilitations Projects In Urban Buildings, LEPTAB, University Of La Rochelle, France.