*Portugal SB07. Sustainable Construction, Materials and Practices*
*L. Bragança et al. (Eds.)*
*IOS Press, 2007*


# Methodology for the application of sustainable construction

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ABSTRACT: Many recognize the sustainable construction value as it contributes to the reduction of the environmental impact and to the quality, accessibility and productivity increase for whoever lives and works inside buildings. However, its economic advantages, which would be of great incentive for its expansion into the market, are still obscure. The objective of this paper is to present a methodology to assess the cost-effectiveness of the application of sustainable measures into buildings, through actions that establish a balance between environmental, economic and social factors. The methodology is based on the comparison of a case study (a building with application of sustainable concepts) with some reference buildings that will allow to show the triple bottom line added values. The aim is to achieve an optimum balance point, with an acceptable pay-back time, and to provide evidence of good economic results that encourage the investment into sustainable construction.

## 1 INTRODUCTION

This article was prepared with the objective of highlighting the subject of sustainable measures in building construction, a concept which has been commonly rejected for one main reason, its cost effectiveness. This problem is linked to some key issues:

- The lack of financial support, direct incentives and understanding of different advantages associated to sustainable buildings by governments, financial institutions and insurance companies.
- Builders and promoters in the real estate market have maintained a basic behaviour (and interest) to look for standard solutions that avoid an increase in the initial cost (investment) of new projects (construction phase). This way, they are transferring operational costs associated to the life cycle of the building to future owners.
- Finally, it is commonplace to observe the general conduct (building stakeholders) that is characterized by a restricted ability to consider the real costs generated during construction and operational phases in buildings. These costs are not considered or introduced in the market price formula, nor are they considered in the planning phase. Simply, they do not exist for building stakeholders. Some of these costs include: wastes, diseases and emissions (pollutants or $CO_2$).

For this reason some countries have been trying to develop different tools for economical and financial feasibility as well as, promote financial support, through incentives and subsidies that encourage the public and private investment into Sustainable construction. These are recognized by its demand-efficiency in energy (25 to 30%) and water, less volume of construction residues and the use of durable materials (Kats, Gregory, 2003).

In addition, it is possible to observe better indoor environmental quality, an increase in productivity among workers, a reduction in maintenance costs and other operational costs. On a global scale, the incentive results of sustainability in construction may provide an increase of 10 million new jobs (Sellier, Dominique, 2003), a decrease in taxes associated with a reduction in public health expenditure, and a reduction of CO2 emissions (including consequences). As mentioned, direct benefits of sustainable buildings, are not only addressed to builders and end users, but also to other stakeholders involved in the construction, from the designers to insurance companies.

## 2 TOOLS TO ASSESS SUSTAINABLE CONSTRUCTION

Different countries have been developing studies and financial tools with the main purpose of implementing Sustainable construction and disseminating a new mentality into the marketplace. Many of these studies are based on tools to assess sustainability which are divulged in a country and tailored to its reality, such as LEED (Leadership in Energy and Environmental Design) in the USA, Breeam (Building Research Establishment's Environmental Assessment Method) in the UK, Casbee (Comprehensive Assessment System for Building Environmental Efficiency) in Japan, among others.

Defined by a methodology and an evaluation system, these tools aim to classify and recognize a sustainable building, and at the same time, they work as a guideline for builders and project designers. A well-known example is the research carried out in the United States, where 33 buildings were compared (certified buildings or in the certification process, by LEED) with other conventional buildings. In this analysis, certain assumptions were used such as discount rates -5%; period of analysis - 20 years; annual inflation - 2%.

It was observed in " The costs and financial benefits of Green Buildings" report (Kats, Gregory 2003), that an investment of 2% (on average) over the initial cost (compared to a conventional building), produces financial benefits 10 times higher than the referred investment (for a period of 20 years), considering the analysis of some cost categories, such as consumptions, maintenance, emissions and productivity.

The same report gives us a simple example of how to evidence these benefits. Applied to a real case and assuming that the construction costs in California are about $150/ft2 to $250/ft2, increasing 2% to these values, it would be equal to $3/ft2 and $5/ft2, respectively. The cost effectiveness analyzed in 20 years would be equal to $48/ft2 and $75/ft2. If these values did not include the inherent benefits concerning CO2 emissions and productivity (just considering the reduction of energy and water demand, and less volume of waste) these would be around $6/ft2 (Kats, Gregory, 2003).

Another interesting study (also in the United States), prepared by David Langdon (2004), had the objective of analysing costs linked to the construction phase of a "green building". This study showed that these costs (construction phase) drive the main decisions in sustainable projects (see figure 1). This report, which compared the construction cost per area in certified and non certified buildings by LEED, accounted for the cost of an information "database" of more than 600 projects (from 19 different States, typologies, locations, sizes and programs).

The referred study concluded that many projects reached the sustainability with their initial budgets or with a minimal additional increase (on average 2%).

In Europe, there are new incentives and legislation seeking to promote more aggressive policies in relation to the challenges of sustainable buildings. New studies have been carried out dedicated to cost effective buildings through sustainable construction concepts. These studies have been financed by the European Commission. Examples are the ASCOT model (Assessment of Sustainable Construction and Technologies Cost), a project carried out in 2004 by HQE2R and Cenergia. This tool helps users to implement a cost optimisation of construction in which sustainability measures have been applied.

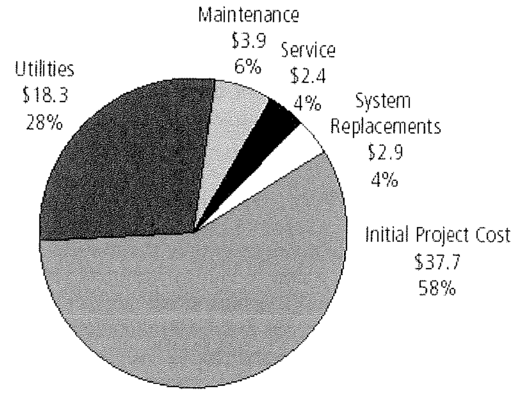


Figure 1. 30 years Life Cycle Cost - Building example
(Megan, Davis et. al, 2005)

There was also an increased interest in the subject of economic feasibility related to assessment tools and projects which can be applied to sustainable construction, such as SHE (Sustainable Housing in European): SHE has the main function of helping in the concept, cost analysis (initial cost and comparison to new buildings) and different options to obtain a higher viability of sustainable measures in projects. Another project, also co-financed by the European Commission, is the LCC-IP –"Guidebook-Integrated Planning for Building Refurbishment Taking Life-Cycle-Cost into Account". This project was constituted by several European case studies where an optimised relation between sustainable measures and cost – benefit analysis was demonstrated. Finally, it is important to make reference to the new government calendar in the UK, regarding the new "Zero Carbon Emissions" program in new houses.

These studies demonstrated that a substantial amount of additional investments made in sustainable projects, are based on specific costs such as simulations, introduction of new technologies and integration of sustainable practices into the project. The studies also evidenced that it is always important to introduce these measures as soon as possible, mainly in the design phase.

## 3 ECONOMIC FEASIBILITY ADAPTED TO THE PORTUGUESE REALITY

The above mentioned studies were carried out according to their national contexts. Thus, this paper intends to show a methodology that is being developed to assess the cost-effectiveness of some sustainable measures to be applied to commercial buildings, adapted to the Portuguese reality. The study will be carried out according to criteria of sustainability assessment tools based on "SbTool"- Sustainable Building Tool (still in the pilot phase to be adapted to the Portuguese case). The various stages of this methodology are outlined in figure 2 and described below.

### 3.1 *Guideline for sustainable construction and action analysis (1st step)*

The first step or the proposed methodology consisted on the development of a "Guideline for sustainable construction", a Manual with more than 400 actions adapted to Portugal, divided into five categories and identified in different project phases: pre-design, design, construction, operation and demolition. The categories are divided into:

- Planning;
- Energy Management;
- Water Management;
- Materials, resources and waste;
- Indoor Environmental Quality.

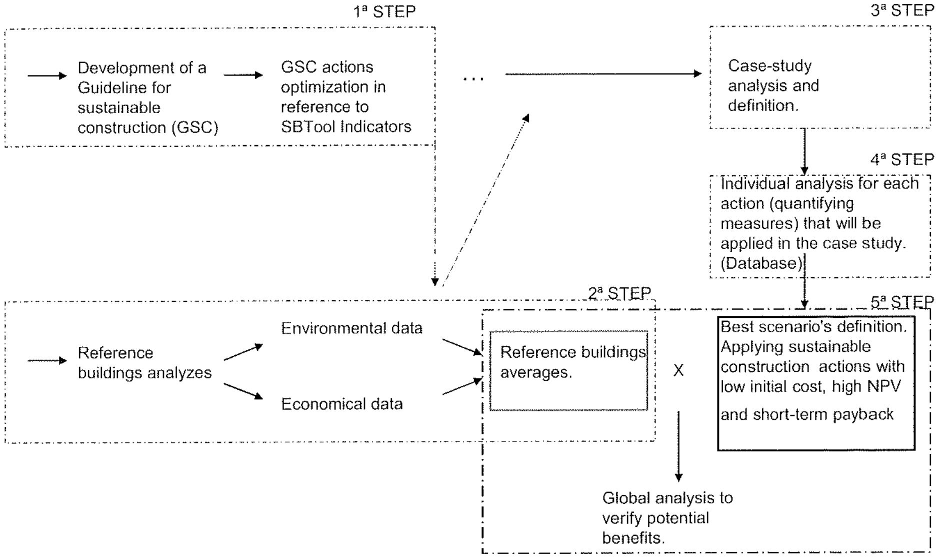


Figure 2. Structure of the proposed methodology.

As the implementation of 400 measures (from the referred Guideline) would be quite a complex procedure, an optimisation of the actions for analysis and validation was carried out based on the SBTool indicators, in reference to the following criteria (see figure 3):

- Specific analysis of just one of the project phases. In this case, the design phase will be examined as it is considered the most relevant to the validation (or application) of sustainable measures into Buildings.
- Only the indicators able to be quantified in the design phase are going to be considered as they allow for a larger impact during the building life cycle. The indicator categories to be analysed are Energy, Materials, waste and Water.

For an economical and environmental evaluation through this methodology, an individual application will be necessary. This will be demonstrated later in step 4.

### 3.2 *Reference building definition (2nd step)*

At the same time that actions were optimized through SBTool indicators, environmental and economic data have been collected on three existing Shopping Centres in Portugal (which used equivalent construction methods). These commercial buildings belong to the Chamartín Real Estate Company.

Through the obtained data of those buildings, which will be referred as "reference buildings", it has been possible to establish efficiency indexes (consumption/m$^2$/year and consumption /1000visitors/year) as can be seen in tables 1 and 2. In addition to these indexes (energy, water, CO2 emissions, recycled and non-recycled waste), global values are going to be compared with national and international "benchmarks" (see table 3). Besides, these can be analyzed according to the IEE (index of energy efficiency), specified for shopping centers, which is comprised by the law 79/2006 (that emerged from the transposition of the EPBD - Energy Performance Building Directive into the Portuguese law) and that it can be visualized in the table 4.

It is important to point out that the shopping centres are situated in different locations, thus different climatic factors were obtained for the "reference buildings". A basic comparison of the average values showed by the three buildings would be incoherent, as they would reflect the different climate features of the buildings performance.

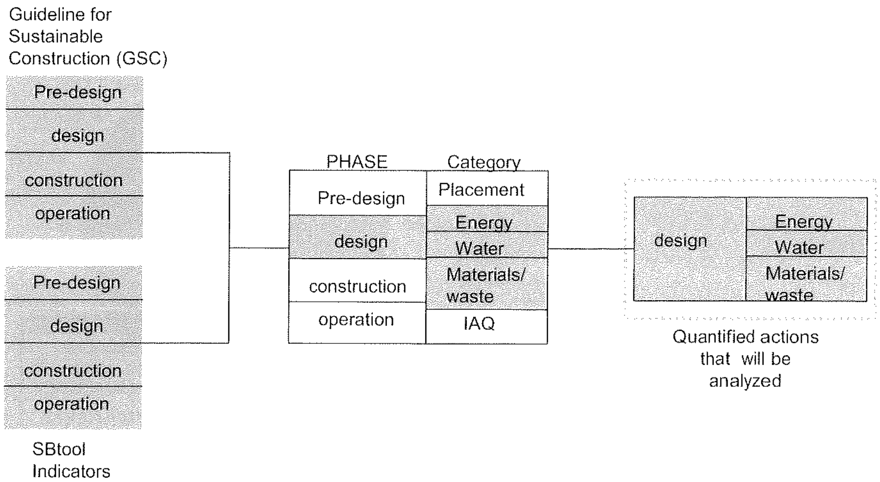


Figure 3. Selection procedures for the optimisation of the indicators to be analysed.

With this in mind and influenced by the methodology used in the Decree-Law 79/2006 to define the IEE index (Energy Efficiency Index) for different building typologies, as referred above, climatic correction factors are going to be applied to these shopping centres located in Coimbra (DVC), Porto (DVP) and Vila Real (DVD), when necessary.

Through these results, it will be possible to establish a comparison, on an economical and environmental level, between the "reference buildings" and a "case study".

Table 1. The efficiency index of the total demand (resources) and Chamartín's average per sqm (without climate correction).

| DVS demand /sqm (construction area -GLA -Parking) | | | | | | | | 2006 |
|---|---|---|---|---|---|---|---|---|
| | *Economical data* | *Environmental data* | | | | | | |
| | Euros | Energy | | Waste | | $CO_2$emissions | Water | |
| | Euros/m$^2$ | kWh/m$^2$ | tep/1000m$^2$ | Recycled /m$^2$ | Non recycled / m$^2$ | $KgCO_2$/ m$^2$ | m$^3$/m$^2$ | |
| DVP | 32.96 | 474.86 | 137.71 | 6.91 | 20.87 | 196.59 | 0.83 | |
| DVD | 22.12 | 283.50 | 85.07 | 6.24 | 11.08 | 117.37 | 0.50 | |
| DVC | 29.43 | 370.69 | 107.50 | 6.79 | 21.45 | 153.46 | 0.79 | |
| Average | 28.17 | 376.35 | 110.09 | 6.65 | 17.80 | 155.81 | 0.71 | |

Table 2. The efficiency index of the total demand (resources) and Chamartín's average per 1000 visitors.

| DVS demand /1000visitors | | | 2006 |
|---|---|---|---|
| | *Environmental data* | | |
| | Energy | $CO_2$emissions | Water |
| | KWh/1000visitors | $KgCO_2$/1000visitors | m$^3$/1000 visitors |
| DVP | 1458.80 | 603.94 | 2.56 |
| DVD | 1265.24 | 523.81 | 2.24 |
| DVC | 1105.02 | 457.48 | 2.39 |
| Average | 1276.35 | 528.41 | 2.40 |

Table 3. The average efficiency index of Shopping Centers - International benchmarks. (Source: CIBEUS and other researches).

| Annual Average energy Intensity (existent Shopping Centres) | | | |
|---|---|---|---|
| | GJ / sqm | KWh / sqm | Kgep / sqm or Tep / 1000sqm |
| Canadian Shopping Centre average | 1.30 | 361.40 | **105** |
| UK Shopping Centre average | 1.04 | 290.00 | **84** |
| The efficiency index specified for the EPBD in Portugal | 2.30 | 655.00 | **190** |
| Portuguese reference building | 1.35 | 376.35 | **110** |

Table 4. The efficiency index, specified for the Shopping Centre in agreement with the decree-law 79/2006 (EPBD, 2006)

| Existent buildings | | |
|---|---|---|
| Activity types | Building tipology | IEE (Kgep/ sqm.year)or (Tep/1000sqm.year) |
| Commercial | Commercial centre | **190** |
| **New buildings** | | |
| Activity types | Building tipology | IEE (Kgep/ sqm.year) or (Tep/1000sqm.year) |
| Commercial | Commercial centre | **95** |

### 3.3 *Case-study definition (3rd step)*

This methodology will be applied to the largest Iberian Shopping Centre, which also belongs to "Chamartín Imobiliária S.G.P.S., S.A". The building is being constructed in Amadora, near Lisbon with a total construction area of 423.000 $m^2$, including parking and 122.000 $m^2$ of GLA (Gross Leasable Area). This project was designed with a new concept brand for Shopping Centres, named "Dolce Vita", a world market reference. It will include wide reading spaces, stores, a food court, recreation areas and supermarkets.

The chosen typology is quite relevant (in relation to its dimension) since a commercial building of this size will have high environmental, social and economical impacts (Environmental impact, resulting from its construction and management, social and economical impacts, resulting from future changes in local reality, employment and road flow increases).

An evaluation of the shopping centre, which is presently in the construction phase, has been carried out in order to verify if any sustainable measures have already been applied. Environmental and economic performances related to the referred measures (already applied) are going to be identified and the probability of the building (through simulation) reaching SBTool indicators will be evaluated.

### 3.4 *Cost-effectiveness of sustainable construction Indicators and database creation (4th step)*

In this stage, the cost-benefit analysis of each sustainable measure (applied individually) will be analysed through a simulation carried out in the selected commercial building previously mentioned. The information will be organized in a database that is structured like shown in figure 4. Firstly, the information will be organized by categories that can be quantified (energy, water and material). Afterwards the information will be structured according to the identification in the SbTool. Regarding to the figure 4, it is possible to understand the referred adaptation, because the information utilized in the 2$^{nd}$ and 3$^{rd}$ rows result from the SBTool organization.

The expected results for each measure are the investment cost, generated NPV (Net Present Value) and the payback period. These measures will be divided into 2 groups with different reference values, such as score 3 "good practice" and score 5 "the best practice", as defined by SBTool benchmarks (see figure 4). The fulfilment of the database will follow the following steps:

**1.** Identification of SBTool indicators that correspond to the project phase and that will be analysed in the database. For each indicator, there are actions to reach objectives.

**2.** Identification of actions, which were already identified in the studied building, and which consider the SBTool indicators in the database. Analysis of actions should be accomplished through the comparison with conventional actions used in the reference buildings.

**3.** Identification of actions that were not found in the studied building and that should be filled out in the database. Analysis of these actions should be accomplished through the comparison with present existing measures in the studied building, regarding potential changes.

### 3.5 *Best scenario formulation – Sustainable Building (according to the application of the studied action) - (5$^{th}$ step)*

After completing the database, the ideal definition of best scenario will be accomplished. This scenario will be made up of actions that have a tendency which is oriented for such characteristics, such as: low initial cost, high NPV and short-term payback, which assure a "good practice" level, according with SBTool methodology.

The selected actions with the referred characteristics, require that other actions will be added (with different characteristics), thereby, assuring the SBTool validation in the execution phase of the different categories (energy, water and materials).

*Apliccation example*

Case-study: DVT Shopping Center **[A]**
Type ocupancy: RETAIL and Office
Phase: Design Phase
Region Location: Amadora_Lisboa

| Related category | Issues | SBTool Intent | Actions already proposed | score 3 | | | score 5 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Investment cost | | | | | | NPV (20 years) | PayBack |
| | | | | L | M | H | L | M | H | | |
| Energy | B3.1 | Plans to use off-site energy that is generated from renewable sources | ☑ | | | x | | | | | ??? |
| Water | B5.3 | Design measures and management plans to limit the use of potable water for building systems and occupant needs | ☐ | | | | | | | | |

**[B]** **[C]** **[D]** **[E]**

[A] -Building`s description

[B]- Indicators that will be quantified, according to the following categories: energy, water and materials.

[C]- Issues - Identify the benchmarks that are analyzed by SBTool (for instance: B.3.1 is an indicator of renewable energies, which are included in the "Energy and resource consumption issues).

SBTool Intent - Actions to accomplish the benchmarks objectives.

[D]- Identification of Sustainable Actions already existent (or not) in the case study.

[E]- Cost benefit analysies for each action, identifying:

Investment cost: L- Low cost
M- Medium cost
H- High cost

NPV (20 years) - Net Present Value - the net result of an investment, expressed in today`s euros; the present value of future cash flows minus the present value of the investment minus any associated future cash outflows.

Simple pay back time - the lenght of time needed to pay back the initial capital investment, usually expressed in years. This is the simplest form of the cost-benefit analysis.

Figure 4 – Database structure – where it will be identified the actions and the indicators under study.

Through the application of the studied measures, a comparison between the best scenario (for a specific typology – Shopping Centre) and the building in study will be obtained. It will include the evaluation and comparison with the present methods and measures carried out in the construction of the building, thereby evidencing a set of results that can be revised in the present project.

The explicitness and transparency that demonstrates efficiency benefits, and how to reach economic value in sustainable buildings, are a decisive incentive for stakeholders and for real estate market in general.

However, it is important to remember that this study will be defined for a specific typology in a certain area. Therefore the result will be conditional and will not allow a direct and immediate application of the best scenario methodology in other projects.

Nonetheless through its main output information (costs definition, database output and new methodology), this study can serve as an important guideline to help different stakeholders involved in new sustainable building projects focused on economical benefits.

## 4 CONCLUSIONS

This paper seeks to define methodologies and objective contents to achieve newer and larger real estate projects (services /commercial), supported by sustainability concepts.

The use of "SBTool" in this study intends to reach desirable results through the use of a rigorous and recognized tool among Universities and Academic environments. On the other hand, it has been positioned as an essential resource for study and development of the Sustainable Building Evaluation.

Finally, this study seeks to define new methodologies and analysis aiming to integrate different action fields such as sustainability, functionality and economic feasibility (cost effectiveness) which more than often are used separately.

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## 6 ACKNOWLEDGEMENT

The authors would like to thank to FCT- Fundação para a Ciência e a Tecnologia, for grant given to the first author of this paper.