Guidelines for sustainable refurbishment of residential buildings

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ABSTRACT: This paper gives an overview of the objectives in a research project currently under development, which is intended to provide a guideline for the sustainable refurbishment of existing residential buildings. It is based on the adaptation of the criteria defined in the methodology of evaluation and certification of sustainability of buildings: SBTool^{PT}. Aiming to develop a guideline on sustainable refurbishment, the present research project investigates two different cases, in order to find out how the refurbishment is done and which possibilities and barriers there are to achieve a sustainable refurbishment. It also aims to find the best rehabilitation practices, and more sustainable solutions, which enhance the balance between environmental and economic benefits, suitable for the needs of the users. This paper identifies the aspects that should be improved and also identifies new parameters of evaluation, presenting a list of different indicators, while establishing new values for the conventional practices and best practices (benchmarks) applicable in the refurbishment of residential buildings. The final outcome of this research work is to give guidance on how to quantify the indicators of SBTool^{PT} during a refurbishment project and also to help the residential building owners to understand the importance of implementing the principals of sustainable refurbishment.

1 INTRODUCTION

The building sector in Portugal has a significant weight in the economy, accounting for a significant portion of investment and employment, but the present context of the construction industry in Portugal is marked by a decrease in new construction. This is the result of the current economic crisis, and the existence of a housing surplus with a large number of buildings in need of rehabilitation. This presents a prospective change in the sector in search of alternatives.

The built environment in Portugal comprises of approximately 3.3 million residential buildings. Among the 3.3 million residential buildings there are approximately 5.8 million dwellings. Despite the trend experienced since the 90s of decrease in new housing construction, the current average in Portugal is 1.7 dwellings per family (INE, 2011).

If we look at time these buildings were built, we see that most of them were built before the regulations on the thermal performance of buildings (RCCTE), published in 1990 (Fig.1).

This information makes evident the lack of thermal requirements and concerns at the time of construction. Figure 1 reveals that 71% of buildings consume high amounts of energy, while attempting to achieve the current conditions and minimal thermal comfort inside the buildings.

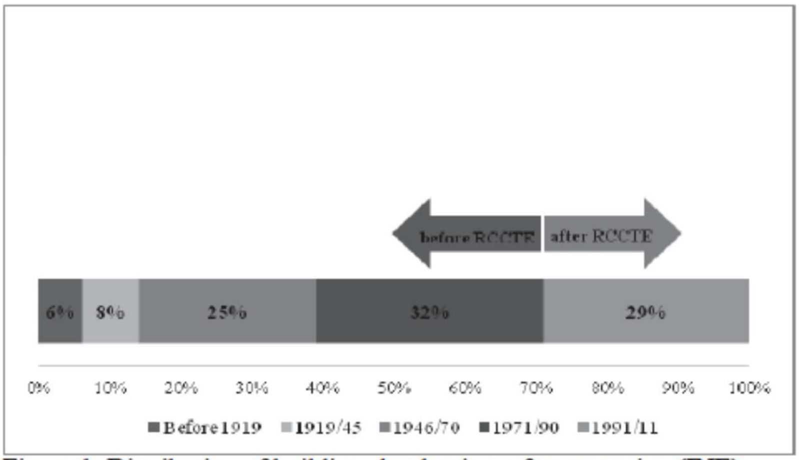

Figure 1. Distribution of buildings by the time of construction (INE).

At the same time, there is an increasing degradation of the building stock, in particular in the housing sector. For example in accordance with the statistical data (INE, 2001), in 2001 nearly half of existing buildings were in need of repair Figure 2.

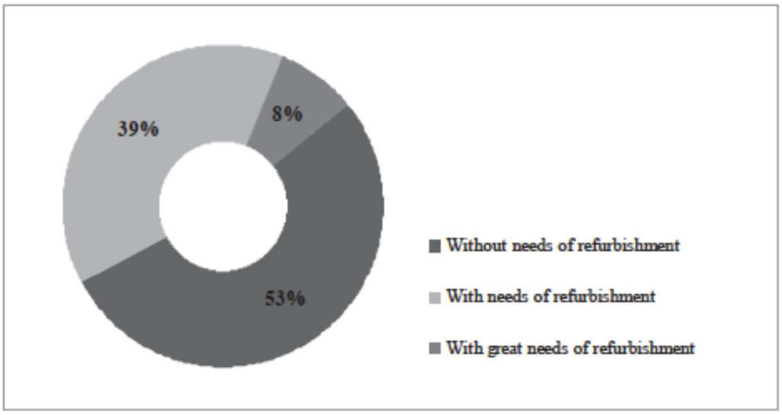

Figure 2. Distribution of buildings by needs or refurbishment (INE).

This trend of reduced activity in construction of new buildings, together with the effects of the contemporary model of development, requires a rethinking of how to plan, use, and redevelop the cities and especially the housing.

The construction industry is one of the activities with greatest impact on the environment and natural heritage, as well as the built environment and architectural heritage. Bearing in mind the rising costs of energy and climate change, this awareness is awakening to the importance of an environmental priority for sustainable development and construction. New challenges are emerging, as are new approaches related to energy, the environment and ecology. Also rising from this awareness is a perspective of joint approach to problems (Mateus, 2009).

Recent European guidelines point to a sustainable development model for the adoption of sustainable construction practices and high performance. They promote the use of sustainable materials, the use of renewable energy, and energy conservation in order to reduce energy dependence.

The evidence that the promotion of greater energy efficiency in buildings, by incorporating more sustainable building solutions and the use of renewable energy, leads to the optimization of environmental performance and energy, the improvement of user comfort and reduced energy bills. It also reveals the latent potential in the rehabilitation process and qualification of the urban built environment.

Although there are already guidelines for the principles and criteria to be used in the design of new sustainable buildings, when the aim is to turn a conventional existing building into a sustainable one, the rehabilitation process becomes more complex.

The rehabilitation of a building is intended to give adequate performance characteristics and operational safety, at structural and building fabric levels, or to grant it new functional skills, determined on the basis of rehabilitation options pursued, in order to allow new uses or use the same performance standards at a higher level (Decree-Law 307/2009).

The rehabilitation of existing buildings is a systematic process applied in the course of its life, due to the identification of actions for improvement, operational improvements and maintenance to ensure its continued modernization and performance over time.

Rehabilitation is seen as a process with different levels of intervention, comprehensive and systematic, able to optimize the way the building, equipment and systems work together. Rehabilitation focuses on improving the performance of the building, aiming to achieve the current standards of comfort and quality required by the users of a functioning building.

Then, it is possible to identify the following primary objectives of a rehabilitation process, which determine the level of intervention:

- Reduction of energy bills;
- Improving the performance of equipment;
- Improved indoor air quality;
- Increased level of user comfort;
- Increased life of the building and equipment.

Considering the needs, interests, the financial capacity of the users or owners of buildings and the current conservation of the building and equipment, the rehabilitation of residential buildings tends to take on two levels:

- Works of reconstruction or expansion of one or more buildings, after total or partial demolition, enabling formal and structural changes.
- Works by remodelling on a smaller scale, following the routine preventative maintenance or remodelling of planned projects. In this group, works include the replacement of exterior covering materials or roof; the renewal and modernization of windows (frames and glass); changes in heating systems and the replacement of lighting fixtures and water appliances (faucets, sanitary facilities, etc.).

Therefore the intend of this research is to evaluate how it is possible to combine the rehabilitation process with the principles of sustainability, and this study focuses on the use of a recognized methodology for the assessment of sustainable construction. This allows to determine the quality of existing buildings, and to define the guidelines that can effectively transform them into sustainable buildings, leading to the achievement of the sustainable rehabilitation goals.

2 THE SBTOOLPT METHODOLOGY

The Sustainable Building Tool is a sustainability building assessment method originating in an adaptation of its international version. The Portuguese Tool is specified to assess new residential buildings from design phase. The assessment method considers the expected behaviour of the entire building.

The basic principle provides the assessment from the preliminary stages of a construction project, and immediately gives the expected result for the sustainability of the building. This provides the possibility to introduce measures to improve its performance during the prospective planning.

The SBTool^{PT} system was designed to be used to plan new buildings and buildings subject to rehabilitation works, including large-scale demolition, reconstruction and expansion of buildings. The end result summarizes the behaviour of a building in relation to the three dimensions of sustainable development (environmental, social and economic) and compares the building under assessment with two benchmarks: conventional practice and best practice. At the end, the performance of a building is measured against the categories and sustainability indicators listed in Table 1, and the level of sustainability is categorized on a qualitative scale (Bragança, 2011).

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

Dimension	Categories	Sustainability indicators
Environment	Climate change and outdoor air quality	Construction materials embodied environmental impact
	Land use and biodiversity	Urban density
		Water permeability of the development
		Use of pre-developed land
		Use of local flora
		Heat-island effect
	Energy efficiency	Primary energy
		In-situ energy production from renewable
	Materials and waste management	Materials and products reused
		Use of materials with recycled contend
		Use of certified organic materials
		Use of cement substitutes in concrete
		Waste management during operation
	Water efficiency	Fresh water consumption
		Re-use of grey and rainwater
Society	Occupant's health and comfort	Natural ventilation efficiency
		Toxicity of finishing
		Thermal comfort
		Lighting comfort
		Acoustic comfort
	Accessibilities	Accessibility to public transportations
		Accessibility to urban amenities
	Awareness and education for sustainability	Education of occupants
Economy	Life-cycle costs	Capital cost
		Operation cost

The normalized values of the evaluation are converted to a scale from A+ to E, where the best practice is A and the conventional practice is represented by the character D.

The structure of this evaluation system allows the retrieval of the grade performance achieved by the building at the level of each of the categories or dimensions evaluated simultaneously, and an overall score for the aggregation of different performances.

3 METHODOLOGY AND OBJECTIVES

The study provides analysis and proposes a restructuring of a methodology for assessing the sustainability of construction, the SBTool^{PT}. It aims to develop a complementary tool to support the development of rehabilitation projects to reward the adoption of measures and solutions that identify with sustainable principles, integrating the principles of eco-efficiency with the economic constraints, social equity and cultural legacy.

The study proposes to find the best way to:

- Save energy and water;
- Ensure the health and durability of buildings;
- Improve indoor air quality;
- Plan the conservation and maintenance of buildings;
- Promote the use of eco-efficient materials;
- Minimize waste production;
- Protect biodiversity and surrounding environment.

The ongoing study is based on the assessment of sustainability performance of a group of existing residential buildings, characterized by an aging index that reveals a poor construction quality in thermal and acoustic terms.

The case studies were selected based on predefined parameters such as number of dwellings, building systems, time of construction, and rehabilitation needs.

Considering the initial state of the buildings and the end result achieved or expected after completion of rehabilitation works, it is expected to evaluate and compare the benefits generated by incorporating sustainable building solutions through the use of renewable energy, and the increase in thermal comfort inside buildings, using the principles of sustainability evaluation defined in the methodology $SBTool^{PT}$ for new buildings.

The aim of the study is to analyse each of the parameters considered in the assessment of sustainability and the contribution generated at the final performance of the building when subjected to rehabilitation works.

It is also intended to demonstrate that the adaptation or modification of the reference levels applied to new buildings can represent a significant contribution to setting the right solutions to be applied in rehabilitation works by stimulating the implementation of more sustainable measures and practices.

At the end it is expected that the objectives, used methods and obtained results constitute a motivation for the various actors in the rehabilitation process and qualification of the built environment, contributing to the development of new parameters for the Sustainability Building Assessment Tool - $SBTool^{PT}$. It will also highlight the importance of promoting the implementation of sustainability principles in the refurbishment of residential buildings.

4 CASE STUDIES

4.1 *Bloco 9, Vila d'Este – Vila Nova de Gaia*

This case study is a multi-family housing building. It is one of the most important cost-controlled constructions in Portugal, built in the eighties (Fig. 3).

The buildings in the study, with a total of 67 dwellings, are based in a construction system called "tunnel formwork" and the facades are simple brick without insulation.

The roof is covered with fiber cement, without any insulation solution, as are the terraces. Most of the dwellings have two fronts, facing north and south. The regeneration project includes the rehabilitation of the external envelope - facades and roofs - including some small additional rehabilitation of common indoor and outdoor spaces for public use.

Inside the housing, no work of improvement was planned or carried out.

The rehabilitation works, based in the main actions diagnosis of the anomalies existing in buildings, are:

. Restoration of facades by applying external thermal insulation composite systems;
. Introduction of sun-barriers on the facades;
. Review of the roofs, by placing insulation and new overlay metallic coating on the existing surface;
. Replacement of existing window frames in the common area, entrance areas and stairways, and partially enclose the balconies;
. Rehabilitation of the drainage system of rainwater and fire protection units.

Figure 3. Images of the building after and before refurbishment.

4.2 *Single family dwelling – Vila Nova de Gaia*

This case study is a single family residence, with two floors, built in the sixties. The housing has a granite structure and the facades are covered with ceramic material. The roof is made of ceramic tiles, with a ventilated attic without any insulation (Fig. 4).

The house was remodelled recently, in response to the needs of the current users. The works were performed as following:

. New roof, with the substitution of structure and laying of thermal insulation;
. Introduction of second aluminium window-frames with double glazing, keeping the pre-existing frames and wooden interior shutters;
. Replacement of sanitary facilities and equipment;
. Reformulation of the kitchen space and replacement of furniture and equipment;
. Installation of solar panels for hot water.

Figure 4: Images of the building after and before refurbishment

5 RESULTS

Firstly it should be noted that the results obtained on this phase reflect only part of the study, so the lessons are a small sample of the universe of indicators and benchmarks for evaluation according to the methodology $SBTool^{PT}$.

The study identifies the adoption of solutions and rehabilitation measures aimed at improving certain criteria, which can be implemented individually in buildings without the need for a comprehensive approach.

Rehabilitation is defined based on the benefit expected to supply users' needs, anticipating the immediate resolution of certain anomalies or problems of buildings.

The typical measures implemented in works of rehabilitation are characterized according to the degree of intervention, as indicated in summary in Table 2.

Table 2. Examples of typical measures implemented in the refurbishment projects.

Basic interventions	wall insulation	Advanced interventions	ventilation grids on window frames
	draught proofing		double glazing
	reduce infiltration		solar panels for hot water
	energy saving light bulbs		new, more efficient heating system
	using flow reducers		double flush toilets
	installation of sun-barriers		ground floor insulation
	painting		rainwater harvesting system
	( )		( )

The evaluation of the options adopted for the refurbishment implemented in the case studies allows us to attain the following results in terms of sustainability performance in these categories (dimensions and parameters) and identify how certain elements can be recovered.

5.1 *Land use and biodiversity*

The present study reveals that rehabilitation does not contribute to improving the performance of buildings in terms of rates of land use. The total land area and building area are presented as elements with no impact on performance evaluation of the rehabilitation works.

On the other hand the waterproofing area is also defined, but that may have relevance to the performance improvement in the parameter related to the index of waterproofing. In the context of a consolidated urban area, or a dense area of occupancy, the land occupied by construction may not be associated with open spaces, free of constructions.

Most of the instruments for land management have soil sealing rates with ratios higher than considered conventional practice.

However is important to define how to mitigate the effect of waterproofing in urban areas, such as in the case studies, to avoid the associated risks: floods, waterproofing soils and the heat island phenomenon.

The performance of a building at this level is evaluated according to the waterproofing index. Therefore, although it is impossible to match the index of best practice applicable to new buildings, there are micro steps that can be considered and valued:

. The change of flooring materials
. The increase in permeable areas
. The densification of green spaces
. The preservation of trees
. The application of green roofs

In the case study, permeable and impermeable areas remained unchanged, because they correspond to treated areas and green areas for pedestrian and car access to buildings, so that their contribution remained neutral.

Alongside these concerns, the question arises about the treatment of green areas, and use of native plants with low need for water.

At this level, it might be interesting to consider the inclusion and utilization of green space as vegetable gardens, which now begin to assume a greater dynamic in social and economic terms and may be a motivation for the usage of permeable green space.

The sustainable indicator at this level must be the increase of the waterproofing area in the buildings, especially in the urban areas.

5.2 *Energy*

The method SBTool^{PT} promotes the reduction of energy consumption and rewards the increasing amount of energy produced in the building through renewable sources.

The evaluation of new buildings requires compliance with the requirements of thermal regulation currently in force. But applying these requirements to existing buildings may require disproportionately large changes and works to ensure the standard requirements for new buildings.

Considering the case studies, it will be necessary to make some adjustments in the calculation model used, taking into account the effective improvements in the building energy performance by comparing the initial state and final state after rehabilitation. This adjustment will award the various measures of improvement from the most basic to the most advanced, given the benefit generated against the starting point.

5.3 *Materials and waste management*

The recycling of raw materials, materials and household waste is essential for the promotion of sustainability in buildings. A work of rehabilitation as the case study for its characteristics requires the reuse of materials and products on a large scale. Therefore this indicator should be reset, by defining new values for the conventional practice and best practice, adapted to this context work of rehabilitation.

The study allowed verifying that some indicators are not applicable in rehabilitation works where the works do not focus on structural elements and are not provided for significant changes in the interior, as the parameter that considers the use of cement substitutes. So this indicator should be removed or replaced.

In what regards to the management of waste produced in the building during the operation phase, and considering the policy of recycling and waste collection in the county where existing buildings are located, it is understood that in this case, the assessment should be performed taking into account different criteria from that used in the methodology for new buildings.

5.4 *Water*

The approach to the best practice defined for the annual volume of water consumed inside the buildings and the percentage reduction in the consumption of drinking water, requires a careful selection of technologies for water use and appliances. Those measures may be ineffective because the required level of intervention and associated costs.

The implementation of technologies for water reuse or recycling may be inappropriate by the space needed for water tanks, and the destruction and re-construction of gardens.

The case studies showed the lack of openness of the owners to include reservoirs of rainwater in gardens. This implies the destruction of green areas already treated and increases the final cost. However, the installation of small rainwater harvesting systems to collect rainwater from the downpipes should not be excluded.

5.5 *Health and wellbeing*

This category evaluates the levels of comfort and health of the users, based on the conditions of visual, acoustic, and thermal comfort of the buildings, as well as the efficiency of the natural ventilation in the interior space.

In existing buildings, these indicators can be evaluated but will hardly be able to be improved. Therefore the options of functional and formal level to the architectonic level already were decided in the conception phase of the building.

As in other categories, the improvement of the performance of the buildings to this level should be readjusted, awarding the adoption of measures and strategies that enable, even on a small scale, a better performance of sustainability of the existing buildings. For example: as measures of visual comfort, colour changes of the interior and exterior walls or replacement of lighting, have been proven to be simpler and better accepted by the users, rather than the closure or opening of a new window or door on the facade – works which are more costly and require a licence from the town hall.

5.6 *Accessibilities*

In existing buildings, the proximity to amenities and public transport is already determined. Any performance improvement of these indicators is not feasible.

To determine the level of sustainability of rehabilitation, the undertaking of case studies are not vital to the evaluation of these parameters, although the actual location of these buildings is very privileged and able to get high performance that could contribute to a more satisfactory overall score.

However, considering the concerns of users, the accessibility of disabled citizens to the interior of the dwellings should be increased.

5.7 *Awareness and education for sustainability*

The behaviour of users is crucial to ensure efficiency and guarantee the proper maintenance of the buildings. In this sense, the existence of guidelines on the efficient use and maintenance of buildings is essential to ensure the preservation of their quality and value over the years.

The SBTool^{PT} provides the availability of a user manual of the building as a prerequisite. In both case studies, the user manual does not exist. This informative document is not yet well known and widespread. The regulations for new buildings require a technical document of the house, which can be comparable to a user's manual, which incorporates the information relating to the building. On the one hand the inclusion of this requirement as a parameter of evaluation in rehabilitation works may be disproportionate to the implemented works. On the other hand, considering the didactic component, it will be a valuable aid to the user, instilling a better and proper use of the building and preserving its value.

This study focuses on finding the best practices and most sustainable rehabilitation solutions that enhance the balance between environmental and economic benefits, targeted to users' needs. The creation of a guide with relevant information about the processes of rehabilitation of existing buildings, with records of cases, in combination with an adjustment and definition of new indicators and parameters to assess the methodology SBTool^{PT}, may substitute a conforming user manual and provide a mean to achieve the set objective.

6 CONCLUSIONS

From the present study it is possible to conclude that there are several indicators in the current SBTool^{PT}methodology of that need to be adjusted in order to adapt it to be used in the assessment of the sustainability of rehabilitation projects (Table 3).

Table 3. Analysis of the potential for direct application of the parameters used in SBTool^{PT}.
High Potential | Average potential | Low potential

Environment	P1	Aggregate value of environmental impacts of life cycle per m2 of floor area/year	High Potential
	P2	Percentage of utilization of soil available	Low potential
	P3	Index of waterproofing	Low potential
	P4	% of the intervention area previously contaminated or built	High Potential
	P5	% of green areas occupied by native plants	Average potential
	P6	% of the area in plan with reflectance not less than 60%	Low potential
	P7	Consumption of non-renewable primary energy in use phase	High Potential
	P8	Amount of energy that is produced in the building trough renewable sources	High Potential
	P9	% by weight of reused in the construction of the building	High Potential
	P10	% by weight of recycled materials used in building construction	Average potential
	P11	% in product cost of organic base certificates	Average potential
	P12	% by weight of the cement replacement materials in concrete	Low potential
	P13	Efficiency Index of selective deposition of domestic waste	Average potential
	P14	Volume of drinking water consumed annually per capita	Average potential
	P15	Percentage reduction in the consumption of drinking water	Average potential
Society	P16	Potential for natural ventilation	Low potential
	P17	Weight Percent of finishing materials with a low content of VOC's	Average potential
	P18	Thermal comfort level of average annual	Low potential
	P19	Average Daylight Factor Medium	Low potential
	P20	Average level of acoustic isolation	Low potential
	P21	Index of accessibility to public transport	Low potential
	P22	Index of accessibility to amenities	Low potential
	P23	Availability of the user manual of the building	Low potential
Economy	P24	Initial investment costs	Low potential
	P25	Cost of services	Average potential

Using the SBTool^{PT} methodology to assess new residential buildings is not suitable for direct application in refurbishment, especially in smaller refurnishing works (such as for the simple substitution of a roof or windows).

These small changes are not a major contribution to the overall final evaluation, though they represent significant improvements in terms of performance of the building when compared to the initial situation.

There are several limitations in existing buildings that prevent the direct application of the parameters and benchmarks used to evaluate new construction or major rehabilitation works.

The sustainability assessment of the refurbishment should set new standards for best practice and conventional practice, new goals and new results, according to the following points:

The quality of the building and the architectural quality, i.e. the relationship between the building and factors such as orientation, sun-shades, natural ventilation and lighting, accessibility, etc;

. The importance of recognizing the starting point, i.e. the energy and environmental performance of the building before any intervention;

. The recognition of different levels of intervention in terms of refurbishment, from primary to advanced, and the interventions that are most commonly implemented;

. The routines and care demonstrated by users in their relationship with the building when in use and operation, enhancing the execution of maintenance plans to keep the value of the construction over the years;

. The concern for cost minimization;

. The appreciation and respect for the identity of the site.

The adaptation of the methodology SBTool^{PT} to the refurbishment works will ensure the achievement of the objectives outlined in the quest for sustainable construction, contributing to a change in the building dedicated to the rehabilitation, improving levels of performance and quality of existing buildings.

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