Co-Benefits in Building Retrofit – Methodology proposal, tool development and a case-study demonstration

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Manuela Almeida .
Associate Professor
University of Minho
Portugal
malmeida@civil.uminho.pt

Nelson Dias, Civil Engineer, Novo Modelo Europa SA, Portugal, nelsongsdias@gmail.com
Marco Ferreira, Architect, University of Minho, Portugal, marcoferreira@civil.uminho.pt
Ana Rodrigues, Civil Engineer, University of Minho, Portugal, anarocha32846@yahoo.co.uk

Short Summary

The existing building stock encloses a huge potential for actions to deal with climate change and to move towards a sustainable economy, but the decision making process for its renovation keeps hampered by the evaluation of building renovation measures that only considers the direct costs, disregarding other relevant benefits and thus, significantly underestimating the full value of improvement and re-use of buildings, both in local and global economy.

The goal of this study was to identify a broader scope of effects that arise from building renovation and to propose a methodology for their quantification and integration in the decision making process in order to assist owners and promoters in the definition of the most appropriate renovation measures. These effects that arise from building renovation operations have been related with the different packages of renovation measures in order to allow comparing and ranking them through a tool developed for this purpose.

The application of the developed methodology and tool to a case study allowed to confirm the relevance of the non-financial benefits in the final evaluations, proving that not only economic criteria should support decisions in the field. An enormous influence of the categories related to the social aspects was demonstrated, as well as to the environmental parameters, clearly showing that these parameters can change the ranking between the tested renovation packages.

Keywords: Co-benefits; Sustainability; Building renovation; Multi-criteria analysis

1. Introduction

The renovation of the existing building stock is a relevant part of the actions to deal with climate change mitigation [1] and to move towards a sustainable relation with our planet [2]. This happens not only because of the reduction of greenhouse gas emissions that can be achieved by promoting the improvement of the overall energy performance of the built environment, but also by the reduction of resources depletion and minimization of waste production for which new construction is a major responsible.

Although existing buildings represent a huge potential in this areas [3], it has been found hard to fully exploit, mainly because of social and economic barriers that hamper owners and promoters in the decision making process, and mislead policy makers in the development of public support financial schemes and in the design of building directives. One of the common problems associated with the evaluation of building renovation measures is that only the energy savings and

the costs are considered, disregarding other relevant benefits and thus, significantly underestimating the full value of improvement and re-use of buildings at several levels of the economy [4].

In fact, building renovation has several side effects often yielding substantial benefits which can be felt not only at a financial level, but also at the environmental and social levels [5]. These side effects can be felt at the building level [6] by the building owner or user (like increased user comfort, fewer problems with building physics, improved aesthetics), but also at the society level [7] (like health effects, job creation, energy security, impact on climate change).

The goal of this study was the development of a methodology and a tool to support building renovation operations. This methodology should enable comparative analysis of different renovation alternatives in a holistic perspective in order to integrate the global benefits and co-benefits of building renovation in the decision process. The tool is intended to assist owners and promoters in the definition of the most appropriate renovation measures and allows the use of 34 different criteria that covers economic, environmental and social aspects, combined through the use of multi-criteria analysis.

The developed methodology and tool are strongly supported in several sustainability building rating systems such as SBTool – Sustainable Building Tool [8], LEED - Leadership in Energy and Environmental Design [9, 10], BREEAM - Building Research Establishment Environmental Assessment Method [11] and LiderA - Lead for the environment in search of sustainability construction [12] and have been applied to evaluate the renovation process of a social housing neighbourhood dated from the 1950's. This allowed to confirm that the inclusion of other effects besides saved energy and costs, clearly changes the hierarchy of the renovation solutions, and proves that a holistic perspective is necessary to reach sustainable building renovations.

2. The research methodology

The methodology for the integration of co-benefits in the decision making process and for the development of the tool to support the decision process occurred through the development of four essential steps, namely the identification of the benefits and co-benefits related to a building renovation, the assessment and quantification of each one of these benefits, their weighting and ranking, and finally the selection of the multi-criteria analysis tool.

The identification of benefits and co-benefits was performed based on the analysis of a set of methodologies for building sustainability certification [9, 10, 11, 12] and several studies on the evaluation of the benefits of existing buildings renovation [13, 14, 15]. The benefits were organized as evaluation criteria not only allowing their identification but also their evaluation and subsequent ranking. Were thus established 34 criteria for evaluating building renovation solutions, which were organized in 11 categories and by the three dimensions of sustainability: the economic, social and environmental, as described in Table 1.

For each criterion were given mechanisms for its quantification with reference to the different methodologies for sustainability assessment as well as for weighting its relative importance from the various stakeholders or beneficiaries of the building renovation perspectives (builder, designer, residents, promoters, community, etc.). To each criterion it was assigned a relative weight, so as to allow the subsequent weighting of the overall criteria in a single indicator.

Combination of the results of all the criteria to be evaluated was finally executed by multi-criteria analysis, specifically using the 'GREY Relational Analysis' [16] approach. The option was based on the non-limitation of the number of possible criteria to consider in the analysis and also for ease the entry of data. Besides this, results are provided even if not all the information is known. The approach is highly versatile allowing dealing with almost total lack of information to complete information availability. The introduction of data takes place through Excel sheets and the results are immediate allowing examining the various alternatives studied by introducing the values of each criterion and the appropriate relative weight.

Table 1: List of criteria for evaluation of building renovation alternatives

Dimension	Category	Criteria	Weigh (%)
Economic	Costs	Investment	9,0
		Maintenance	4,0
		Use	5,0
	Added Value	Real estate value	5,0
Social	Comfort	Thermal comfort	5,0
		Acoustic comfort	4,0
		Natural light	3,0
		Materials toxicity	1,0
		Air quality	3,0
		Inhabitants annoyance	4,0
	Functionality	Inclusive design	1,5
		Site management	2,0
		Interior layout adaptation	0,5
		Car parking	1,0
	Site integration	Territorial and landscape valorisation	2,5
		Awareness and education	0,5
		Surroundings regeneration	3,0
		Job creation	2,0
		Risk control	1,0
		Heritage values preservation	5,0
	Security	Fire	3,0
		Seismic	2,0
		Other risks	2,0
Environmental	Resources and materials	Materials recycling	1,0
		Materials durability	2,0
		Materials environmental impact	3,0
	Water	Water use	3,0
		Wastewater treatment	2,0
	Land use	Soil reuse	1,0
	Energy	Carbon intensity	5,0
		Renewables use	2,0
		Energy efficiency	6,0
	Waste	Waste treatment	2,0
		Waste production	4,0

3. Presentation and application of REHABILI-Tool to a study case

Based on the described methodology, a tool was developed to support the comparison of the building renovation solutions. The tool is performed based on Microsoft Excel and consists of 34 sheets for the criteria and 3 sheets in which is inserted information about the building, about the renovation alternatives and about the criteria under which the building will be evaluated. As final support to the decision making process, there are 2 sheets where comparative analysis are made out of the available data.

This chapter describes the work done before and after the introduction of data in the analysis tool, relying on the evaluation of a specific case study, namely a residential building located in Bairro Rainha D. Leonor located in Foz do Douro, Oporto.

The analyzed building is included in a renovation program of the Social Housing Neighborhood Rainha D. Leonor promoted and sponsored by the Municipality of Oporto and is presented in Figure 1 (before renovation) and Figure 2 (after renovation).

Figure 1: Building before renovation

Figure 2: Building after renovation (Base scenario)

In order to be possible to perform the calculation of each of the criterion in the tool and consequently compare different renovation scenarios, it is required the definition and characterization of each of the possible building renovation solutions by collecting data to allow the assessment of each criterion.

Once the data entry for each renovation solution is completed, the calculation is done for each criterion and the results are transferred to a multi-criteria analysis tool in order to proceed to the comparative analysis of the selected solutions. This analysis can be done overall or by sector, depending on the transposed criteria for multi-criteria analysis. Obtaining results from the multi-criteria tool is immediate and they can be analyzed both analytically and graphically by the user through specific sheets in REHABILI-Tool.

Within the present case study, three different scenarios for building renovation were evaluated:

- Base scenario: the renovation measures tested were the ones used in the recent renovation of the building. These correspond to the usual measures being used nowadays in current building renovations in Portugal;
- Best practice scenario: the package of measures used correspond to the best practice

currently available in the market, including the use of on-site renewables;

- Maintenance scenario: the original performance and characteristics of the building were kept and only maintenance and conservation measures were implemented;

For each of the alternatives for the building under study, each criterion has been quantified and the values were translated to the multi-criteria analysis tool. Once obtained the results of multi-criteria analysis for different alternatives of the building renovation, these were compared, analyzed and conclusions were found on the best solution for each dimension and still the best global solution through a rating between 0 and 1 which can be observed graphically in Figure 3 for the Base scenario, in Figure 4 for the Best practice scenario and in Figure 5 for the Maintenance scenario.

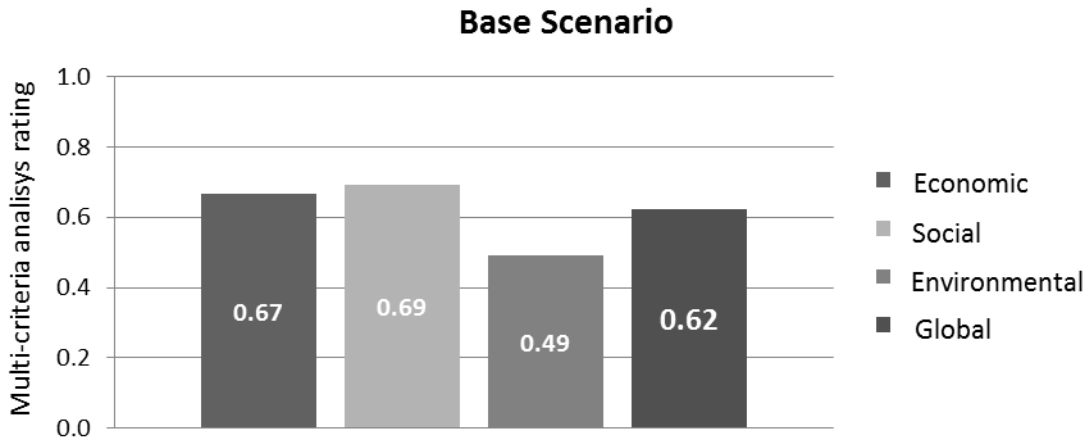

Figure 3: Results from multi-criteria evaluation for Base Scenario

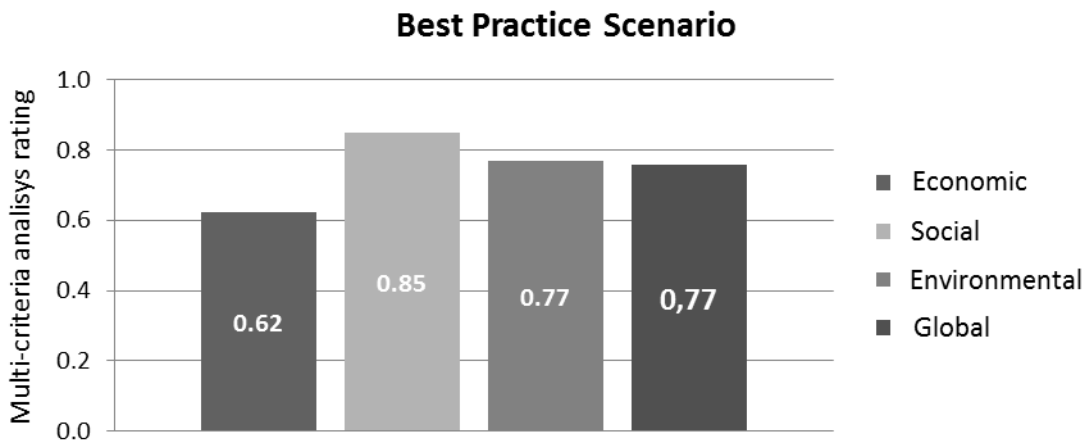

Figure 4: Results from multi-criteria evaluation for Best Practice Scenario

Figure 5: Results from multi-criteria evaluation for Maintenance Scenario

Comparative analyzes by sustainability dimensions held analogously to global analysis but only to the criteria of each dimension independently, allows a sectorial analysis, for the economic, social and environmental dimensions, so as to obtain a large number of perspectives and comparative data to aid in the decision making process.

Figures 6, 7 and 8 show the graphical analysis and comparison of the solutions for the different alternatives with the data of multi-criteria analysis tool for the three dimensions of sustainability.

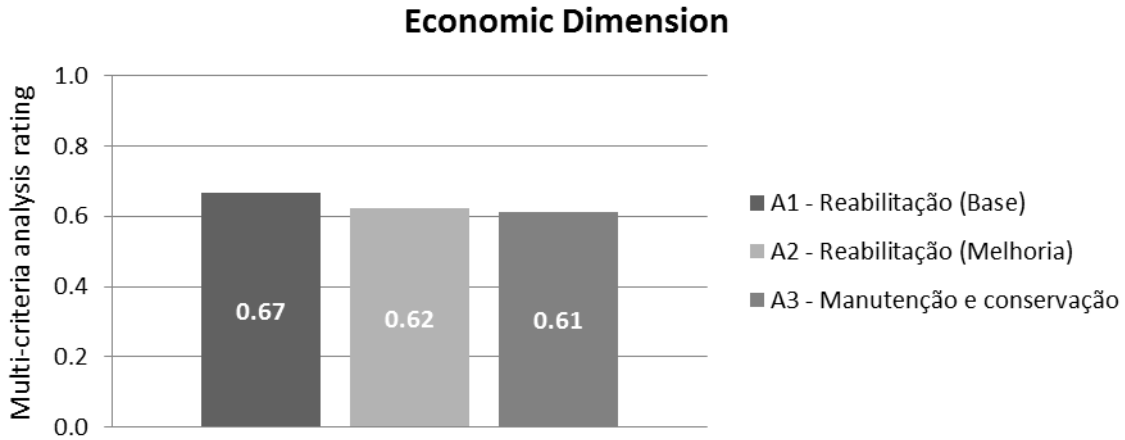

Figure 6: Results for Economic Dimension for the different renovation scenarios

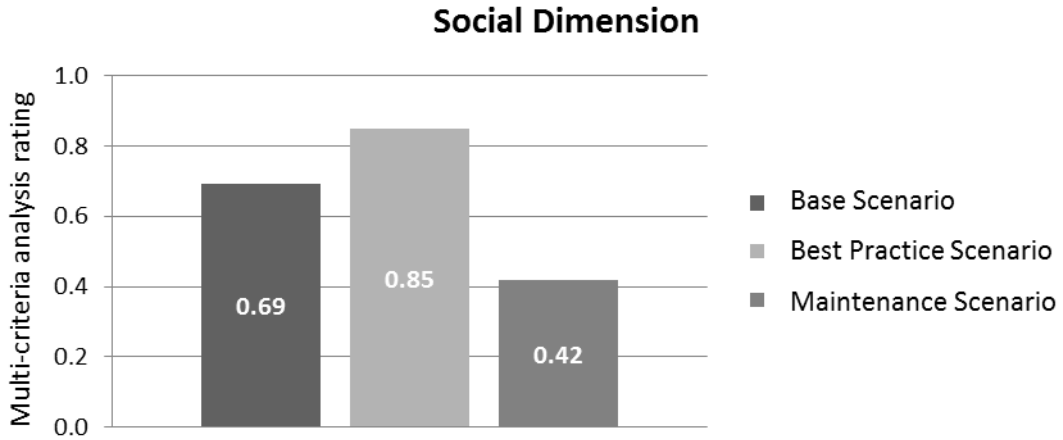

Figure 7: Results for Social Dimension for the different renovation scenarios

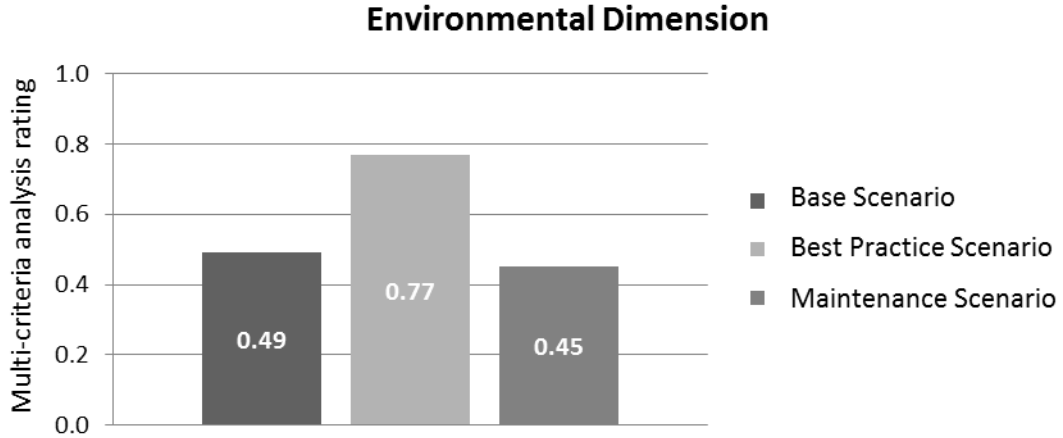

Figure 8: Results for Environmental Dimension for the different renovation scenarios

4. Discussion

From the results obtained and verified on the graphical analysis shown in Figure 9, as well as from previous Figures 3 to 8, it is obvious to conclude that the best studied alternative was the Best practice scenario. This evidence can be explained largely due to differences in classification obtained in the social and environmental aspects. This was the result of the application of the chosen constructive solutions allowing ensuring greater occupant comfort, improved equipment indoors and outdoors, higher level of security for occupants, lower energy costs, lower carbon emissions, lower water costs, lower environmental impact of the materials used and ultimately less production of non-reusable waste.

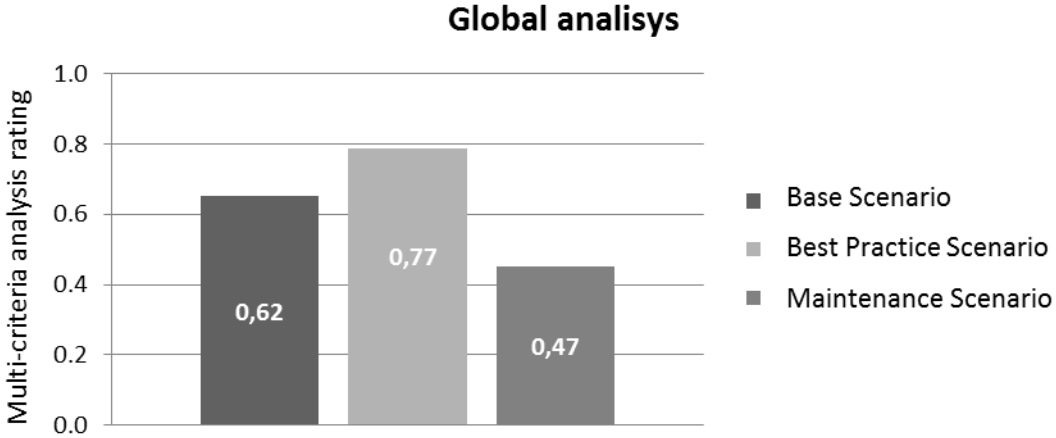

Figure 9: Results for Global analysis for the different renovation scenarios

Yet it is worth noting the slight superiority of Base scenario on the economic side, which is largely explained by the higher investment made in Best practice scenario, which still presents significant improvements in terms of running costs and real estate added value to the building.

Finally, it must be highlighted the poor results obtained with the Maintenance scenario. Despite having in its favor the extremely low value of the investment made, this turns out to be the worst alternative even in the economic dimension due to very high values of running costs and low real estate added value. In other dimensions the results with this scenario are even worse, which may be explained by the reduced intervention in a building that had clear deep intervention needs.

5. Conclusions

The primary objective of this study was the analysis of the co-benefits in building renovation and their integration into the decision making process. It was important to develop ways of helping decision-makers in choosing the best options during a building renovation process according to the particularities of the building under study, allowing that in this decision support process are considered various effects that are usually disregarded.

It was possible to present a method for integrating the benefits and co-benefits of building renovation in a decision process and it was recognized the ability of multi-criteria analysis in dealing with this type of assessment, essentially the ability to handle parameters with distinct magnitudes.

With regard to results, it must be emphasized the relevance of the co-benefits in the final evaluations, which proves that not only from an economic perspective the decisions should be taken, but also from perspectives indirectly related to the renovation measures or issues that do not affect to the same degree of importance different stakeholders. More specifically, it was evidenced the enormous influence of the categories related to the social and environmental aspects in the final standings of each alternative, more specifically in the Best practice scenario, that by adding its

rating in the environmental criteria enabled this to be the solution with the highest overall score. On the other hand, the weak ratings in the social and environmental criteria led the Maintenance scenario to be the solution with the by far worst rating.

These observations allow confirming that although sometimes a solution may not be the most attractive in economic terms can globally be the most effective and adjusted to the building under consideration. This occurs if the building renovation package meets determined criteria where quality of the constructive solutions and efficiency of equipment have great influence, thus allowing for better ratings in social and environmental aspects. This option for the quality of solutions and equipment will also lead to lower usage costs and higher property values after intervention that may justify higher initial investments. Lower affectation of the surroundings, lower resources depletion and less waste production are other relevant benefits that can be achieved with improved renovation packages.

It is intended that the analysis tool may become a practical and useful one for decision makers that through their use can build their opinion in the various building renovation solutions, and may thus decide and choose in a consistent manner, knowing the advantages and disadvantages of the different alternatives.

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