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ScienceDirect

Energy Procedia 140 (2017) 303–313

Energy Procedia

www.elsevier.com/locate/procedia

AiCARR 50th International Congress; Beyond NZEB Buildings, 10-11 May 2017, Matera, Italy

Applications of an Integrated Design Methodology for Regenerative Process of the Existing Buildings

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Abstract

The building sector has been identified as one of the key sectors to achieve the 20/20/20 targets of the EU. In particular, the existing buildings are considered as one of most potential sub-sectors to reach energy and raw materials savings.
This research is integrated in this European context and the main goal is to look for solutions that can be fully integrated in the building system and that can optimize all the sustainable future aspects. A global approach is proposed to generate a comprehensive framework for the building renovation process. It's an "action guide" of the entire regenerative process already applied to different types of buildings. A summary of the results obtained in the buildings regeneration projects are presented.

Peer-review under responsibility of the scientific committee of the AiCARR 50th International Congress; Beyond NZEB Buildings.

Keywords: energy audit; energy refurbishment; sustainable energy development

1. Introduction

In the recent past, human actions have been responsible for "climate change" and nowadays we have to deal with that [1]. We must change the way we live and work in order to avoid the point of no return of our Planet. The building sector has been identified as one of the key sectors to achieve the 20/20/20 targets of the EU [2]. Beyond these targets for the sustainable develop, Europe also aims to obtain a drastic reductions of greenhouse gas emission in the building

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Peer-review under responsibility of the scientific committee of the AiCARR 50th International Congress; Beyond NZEB Buildings
10.1016/j.egypro.2017.11.144

sector (88-91% reductions from the 1990 to the 2050). So all the experts of this sector are called to change the design methods, taking into account a future where resources (energy, economic, ...) will be increasingly limited [3].

One of the main actions is the urban renovation. The aim is to build on the built, without a complete demolition of the existing buildings, in order to minimize the use of resources and the production of waste [4]. The goal is to look for solutions that can be fully integrated in the building system and that can optimize the three different aspects of a sustainable future (environmental, economic and social aspects) [5].

In the presented work, an integrated approach is proposed in order to include all the stakeholders involved in a project and to create a "guide" for the building renovation process.

2. Methodology for regenerative projects

The global methodology for regenerative projects is developed and tested on several projects for the renovation of existing buildings and on the European project called "Renovation of Residential urban spaces: Towards nearly zero energy CITIES (R2CITIES)" (EEB.ENERGY.2012.8.8.3: "Demonstration of nearly Zero Energy Building Renovation for cities and districts"). The methodology focuses on establishing a guide through the renovation process. The aim is to provide the recommendations for integrating the stakeholders, to suggest the tools and methods to use in each stage. In particular it is suggests a decision-making method to choose the best alternatives considering a sustainable approach, that it can be define an "optimization methodology" applied to the renovation process.

The methodology consider two key aspects (see Fig. 1):

- The project organization based on the IPD principles (Integrated Project Delivery®) develop by the ®The American Institute of Architects (AIA National/AIA California Council). This aspect assures the correct involvement of the stakeholders through the process and their communications flows in each phases and assures to improve the collaborative work.
- The project key phases ensures that the design solutions accomplish with the sustainability goals and that all the stakeholder's expectations are met.

All the process is developed by four parallel approaches: management, technical framework, BIM platform and District Sustainability Indicators (DSIs). These aspects are used to perform each phase of the complex requalification process: the Diagnosis phase, the Design phase and the Evaluation phase.

In the following sections a detailed description of the phases are presented, with particular attention to the technical aspects.

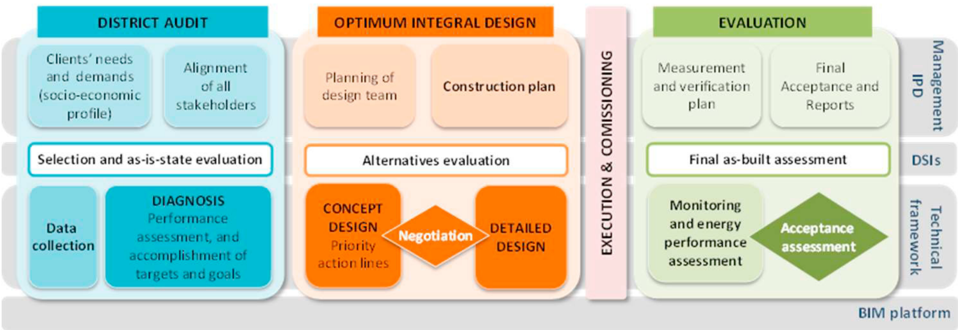


Fig. 1. Structure of the R2CITIES Methodology for requalification project.

2.1. The Diagnosis Phase

The main goal of the diagnosis phase (see Fig. 2) is to set project baseline and clients' needs and demands, to determine the building performance and to identify the main barriers [6].

In the technical approach, after some preliminary operative/management steps (stakeholders expectations, choice of teamwork and of technical tools, ...), the first operative action to do is the data collection. This activity can be split in three levels:

- Environmental level: collection and analysis of environmental boundary conditions data related to the site;
- Typological level: analysis of the specific building aspects linked to environmental aspects;
- Details level: detailed analysis of building characteristics and energy profiles.

The three levels ensure a complete collection of all data needed for the analysis of the actual state of the building. In parallel with data analysis, it must be identified the main barriers affecting the building.

Once data analysis is finished, the building energy classification must be done and it is useful, for the next conceptual design phase, the identification of a priority action line.

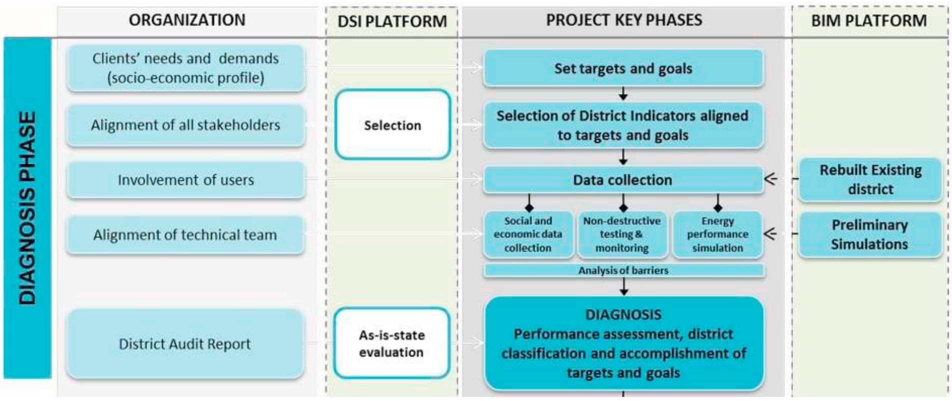


Fig. 2. Structure of the R2CITIES Diagnosis Phase.

2.2. The Design Phase

The design phase (see Fig. 3) is based on project objectives and diagnosis phase results, which will give several suggestions. The aim of this phase is to take select and design all final activities that will be carried out in the building. This phase can be subdivided in two technical parts:

- Concept Design: it is the moment to think up and to simulate all the possible solutions in order to achieve the project scopes and the client's expectations. Each solutions or each group of solutions are analyse in terms of energy savings and costs. The expert analyses the results and then proposes to the client the possible retrofit interventions.
- Detailed Design: when the client decide the best option among all those proposed, the detailed design would be developed.

In the design phase is also included the tendering process, that could be before or after the detailed design. The objectives of the tender is to engage all necessary stakeholders for the implementation of works and to set contractual requirements.

At the end of this process, the construction plan and all the related documents are developed in order to continue with the executions of the works.

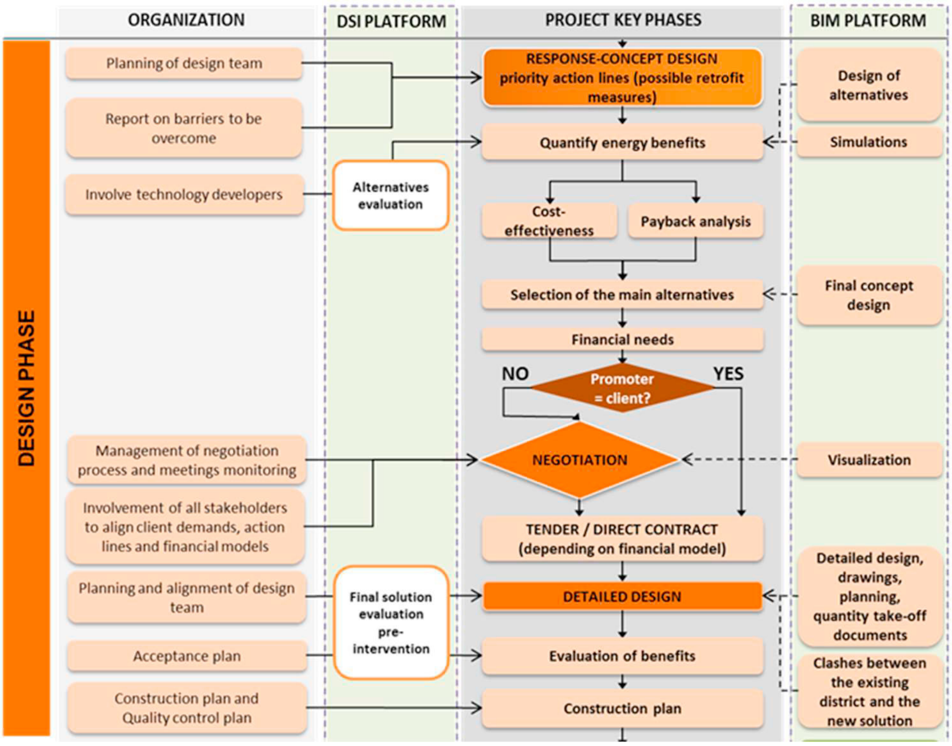


Fig. 3. Structure of the R2CITIES Design Phase.

2.3. The Evaluation Phase

This phase is the final step of the entire process. The aim is to evaluate the building performance, users' acceptance and final as-built (see Fig. 4).

The goals of this phase are to guarantee that the project met all the initial expectations and to evaluate all the teamwork.

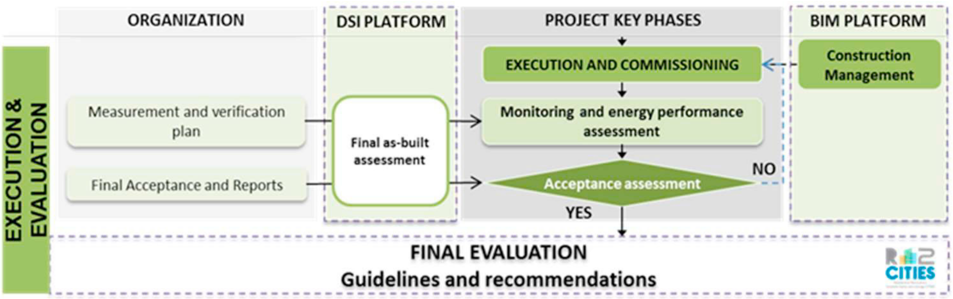


Fig. 4. Structure of the R2CITIES Evaluation Phase.

3. Application of the methodology: case studies

The global methodology presented in the previous section is applied to a huge number of existing buildings in the Genoa's area. In particular, in this paper are presented four case studies of buildings with different kind of use: house, school, office and military barracks (see Fig. 5).

Fig. 5. Localization of the case studies in the Genoa's area.

Each case study is presented with a short description of the actual state and a list of all the possible interventions. Each solution is analysed for different point of view using some indicators, like:

- Energy savings: expressed as annual percentage reduction of primary energy consumption.
- Payback time of the investment: expressed in year calculated with the net present value.
- Durability of the retrofit measures: indicate how the measure will be effective and reliable over time.
- Feasibility of the retrofit measures: assess how is easy or not to implement the solution.

For each indicator ranges are identified to give a score from 0 to 4 points (see Table 1). The solutions that has the highest final score is that one optimize all the considered indicators [7].

Table 1. The chosen scores for each indicator.

Energy Savings		Payback Time		Durability		Feasibility	
0%	0	> 50 year	0	no sufficient	0	no feasible	0
< 10%	1	< 50 year	1	poor	1	high difficulty	1
< 20%	2	< 25 year	2	mediocre	2	difficulty	2
< 40%	3	< 10 year	3	good	3	ease	3
> 40%	4	< 5 year	4	high	4	high ease	4

3.1. Social Housing building – "Washing Machines"

The first case study is a building of the Genoa District named "Washing Machines", due to the presence of many circular portholes on the façades (see Fig. 6). It was built in '80 and this District is one of the three demo site of the R2CITIES European project.

The building structure is made in cast reinforced concrete (depth horizontal and vertical sets: 0.15 m); each dwelling is a simplex floor with double faces (East and West) and there are seven no-heating common spaces where there are elevators, stairs and basement.

a

b

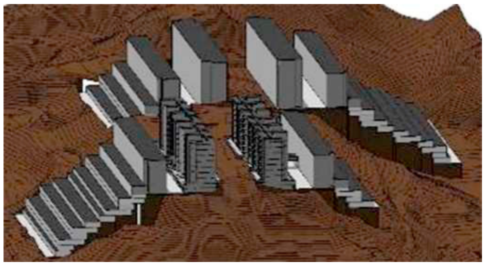


Fig. 6. The Genoa demo site: (a) the “Washing Machines” and (b) the BIM model.

The main characteristics of elements (Fig. 7) are:

- foundation on pilots;
- flat roof;
- vertical walls made from reinforced concrete wall, brick wall with or without internal or external thermal insulation layers;
- Windows of the heating zones with metal frame, double air glazing and roll-up shutter; windows of the no-heating zones with metal frame and single glazing.

Fig. 7. Details of “Washing Machines”.

The actual energy state is inadequate to the energy efficiency limits of the Italian and Regional laws and in general to the idea of “nearly zero-energy building”. After analyzing the actual performances of the building and each characteristic of the envelope and the systems, these energy efficiency solutions are planned:

(a) Thermal insulation of the first floor: addition of new extrados thermal insulation layer.

(b) Thermal insulation of the roof: addition new extrados thermal insulation layer.

(c) Thermal insulation of the façades: remaking of the finishing coat layer with nanotechnology materials, as there is already an external thermal insulation layer.

(d) Thermal insulation of the walls/floors between heating zones and no-heating zones: new external thermal insulation layer.

(e) Thermal insulation of the walls/floors of the no-heating zones: remaking of the finishing coat layer with nanotechnology materials, as there is already an exterior insulation layer, and addition of an extrados thermal insulation layer in the floors.

(f) Windows Substitution (East side - Heating zones): installation of new high energy-performance windows.

(g) Windows substitution (West side - Heating zones): installation of new high energy-performance windows.

(h) Windows substitution (no-Heating zones): installation of new high energy-performance windows.
(i) Heat Generation Plant substitution: installation of new high performance system.
(j) Heat Generation Plant substitution and regulation system substitution: installation of new high performance generation system, installation of zone control systems and replacement of the fan motors with variable speed motors.

Each solution is analysed for all the four indicators and it was done a final classification to evaluate the best solution. In this case study, the results are the two last measures: the heat generation plant substitution (i) and the generation and regulation systems substitution (j) (Fig. 8).

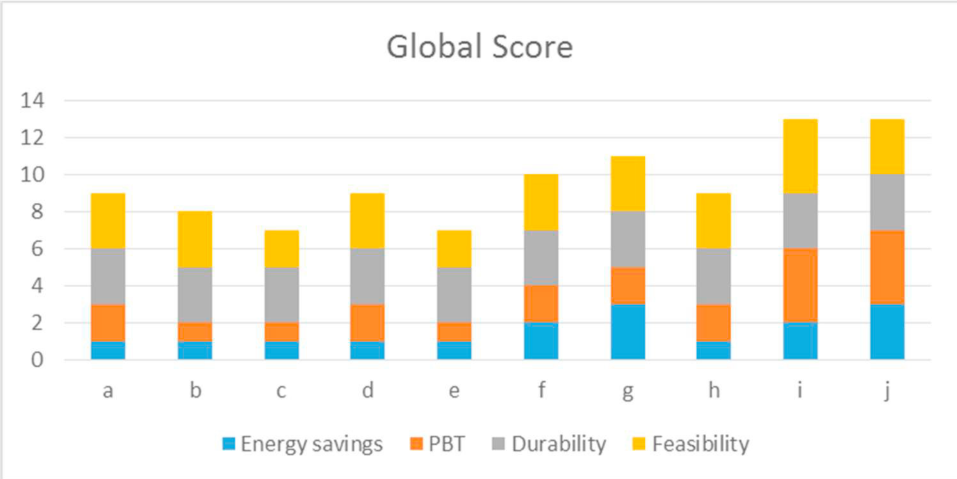


Fig. 8. The global scores for each retrofitting measure of the "Washing machines" building.

3.2. School – "Complesso Scolastico di Borzoli"

The second case study is a school named "Complesso Scolastico di Borzoli" located in the periphery of Genoa and almost 300 people use it (see Fig. 9). It was built in 1976 with a typical precast construction technique and its entire gross volume is about 20250 m^3. The building has a compactness index about 0.6 and it is characterized by a low percentage of transparent elements on the south side, around 15%.

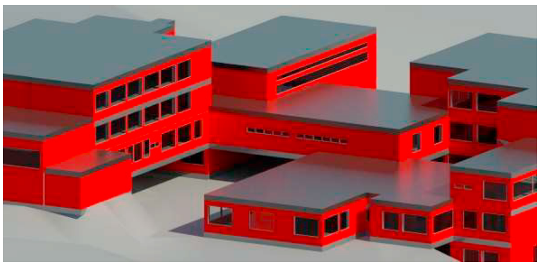
a  b 

Fig. 9. Birdseye view of the school "Complesso Scolastico di Borzoli" (a) and the BIM model (b).

The main characteristics are (see Fig. 10):

- Metal structure;

- Horizontal elements are made in metal and precast reinforced concrete;
- Precast panels with a thermal/acoustic insulation layer for the vertical elements;
- Windows with metal frame and single glazing.

Fig. 10. Envelope details of “Complesso Scolastico di Borzoli”.

The actual performance is inadequate to the energy efficiency limits so are planned these energy efficiency measures:

(a) Walls substitution and Windows substitution: installation of new high energy performance panels and new high energy-performance windows.

(b) Walls substitution and Windows substitution: installation of new ventilated facades and new high energy-performance windows.

(c) Thermal insulation of the walls and Windows substitution: new extrados thermal insulation layer and installation of new high energy-performance windows.

(d) Thermal insulation of the horizontal elements: addition of a new thermal insulation layer.

(e) Thermal insulation of the roof: addition of a new thermal insulation layer.

Each solution is analysed for two indicators: energy savings and payback time of the investment. The best solutions in this case are (see Fig. 11): new ventilated facades and windows substitution (b) and addiction of a new thermal insulation layer and windows substitution (c).

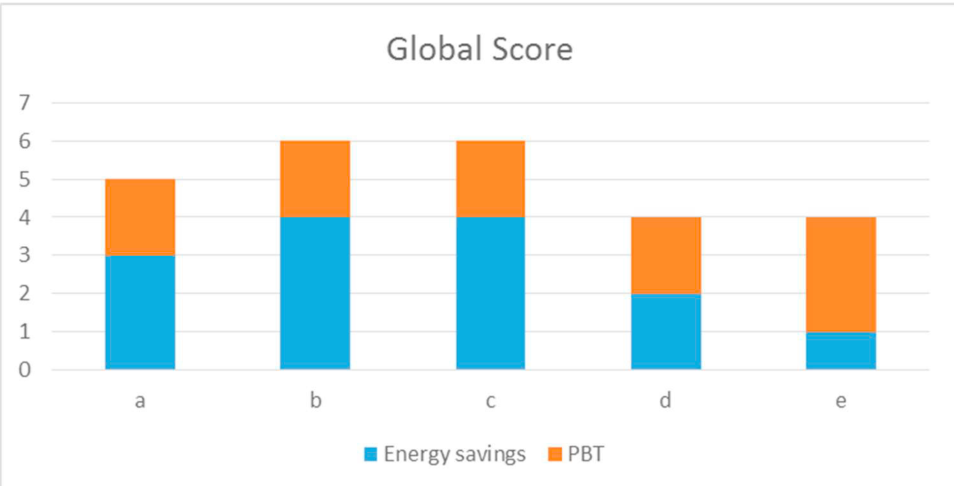


Fig. 11. The global scores for each retrofitting measure of “Complesso Scolastico di Borzoli”.

3.3. Office Building

The case study as office use is a building located in the east side of Genoa (see Fig. 12). It was built in 1981 and now almost 270 people use it. The gross volume is 23000 m^3 and it consists in five floors, four used as offices and a basement used as technical space. The main characteristics are reinforced concrete structure and curtain wall.

a b

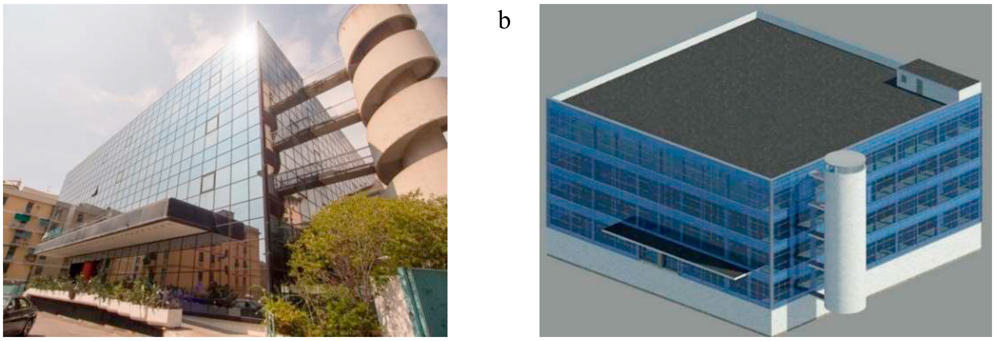


Fig. 12. View of the office building in Genoa (a) and the BIM model (b).

In order to obtain an improvement of the internal comfort and the reduction of the energy consumption, the planned interventions are:

(a) Thermal insulation of the first floor: addition of a new extrados thermal insulation layer.
(b) Thermal insulation of the roof: addition of a new extrados thermal insulation layer.
(c) Windows substitution: installation of new high energy-performance windows.
(d) Thermal insulation of the walls/floors between heating zones and no-heating zones: addition of a new extrados thermal insulation layer.
(e) Thermal insulation of the walls: addition of a new thermal insulation layer in cavity.
(f) Installation of external shadings.

Each solution is analysed for two indicators: energy savings and payback time of the investment. The best solutions is the thermal insulation of the walls in cavity (e) (see Fig. 13).

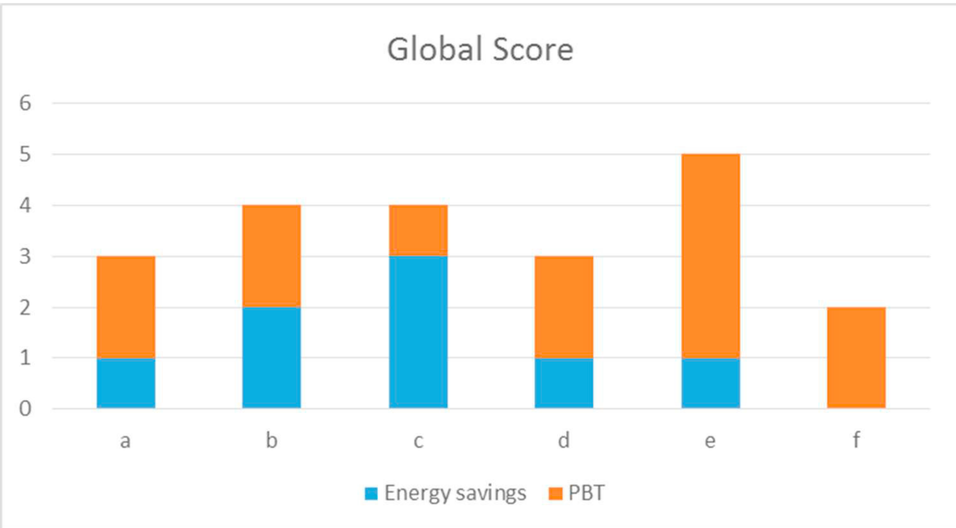


Fig. 13. The global scores for each retrofitting measure of the office.

3.4. Military Building

The last case study is a military building that it was built in 1846 on a previous fortification "above the water", next to the seaside. It is located in the harbour area in front of one of Genoa’s old town.

The older vertical structures is in stone or brick masonry and the horizontal structures are vaults and wooden slabs. In 1960, a new traditional reinforced concrete structure is built on the top of the old fortification: the vertical concrete structures have cavity brick block walls with an external wall covering in thin brick elements or traditional plaster (see Fig. 14).

a

b

Fig. 14. Bird’s eye view of the military building in Genoa (a) and view of the BIM model (b).

In this specific case study, the possibilities of solutions were limited overall by the construction heritage constraints. Therefore, the possible interventions are:

(a) Replacement of original windows with new high performance windows.

(b) Thermal insulation of the walls: fill by polyurethane foam of the air space of the cavity wall.

(c) External thermal insulation system by new layer of Aerogel plaster.

(d) External insulation system with fibre panels.

(e) Installation of thermo-reflective panels behind the thermal radiators in the external envelope.

(f) Regulation system substitution: installation of environment regulator and climatic compensation systems.

Each solution is analysed for two indicators: energy savings and payback time of the investment. The best solutions is the substitution of the regulation system (f), in particular the installation of environment regulator and climatic compensation systems (see Fig. 15).

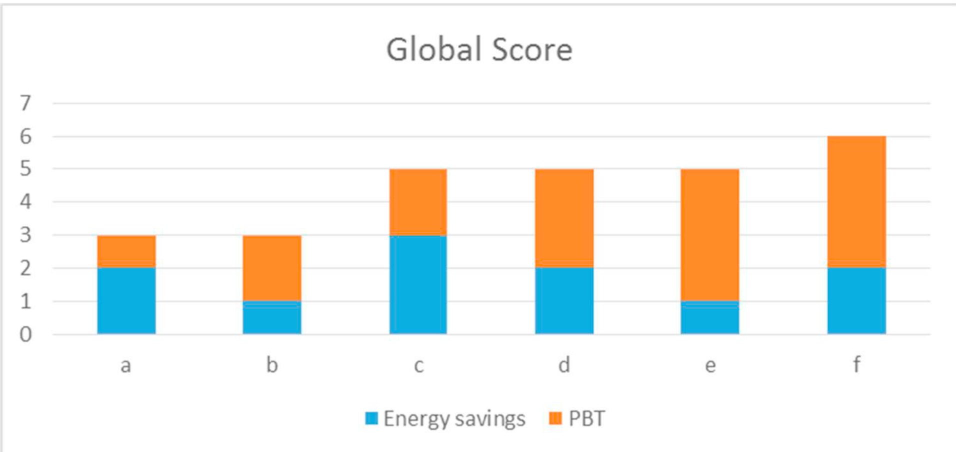


Fig. 15. The global scores for each retrofitting measure of the military building.

4. Conclusion

The integrated design methodology presented is a global approach applying from the beginning to the end of the regeneration project. It was entirely applied only in the first case study; while in the other cases, it was applied until the preliminary project, because the project was not carried out. Nevertheless, the methodology has proven its worth and allowed us to analyze many different and real aspects of a regeneration project.

The operative methodology proposed to classify the technical solutions, considering energy savings, payback time, durability and feasibility, is a first step of a research about the optimization process. In the future, this scoring system would be developed to create an objective optimization tool. This feasible development can improve the replicability, objectivity and quantitative control of the numerical estimates.

About the presented case studies, it is possible to make a summary of the scores for each intervention considering only the energy savings and PBT points (see Fig. 16). From summary, it is evident that have been analyzed more kind of intervention on the building envelope but the best results were obtained with the interventions on plant systems. The only exception are the 6 points obtained in the school because it is the sum of the windows substitution and the facades insulation results. In the specific case of the envelope interventions, the best solutions are the ones on the windows and on the vertical walls. This is because, even with high costs, they change a great portion of envelope surface and consequently to obtain high energy savings. These results confirm that the refurbishment of the systems are more advantageous. This kind of interventions allow to achieve greater energy savings with lower investments.

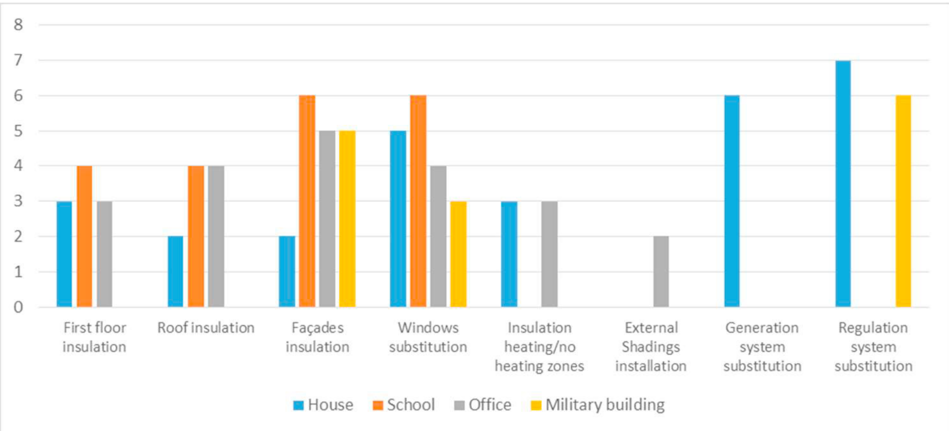


Fig. 16. Summary of the energy savings and payback time scores for each kind of retrofitting measure.

Acknowledgements

Financial support for this study was provided by a grant from the European Commission (Smart Cities and Communities 2011, FP7, R2CITIES European Project, 2013-2018). The authors wish to thank A. Messico, L. Parodi and C. Berardi for their work.

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