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Analysis of different energy conservation strategies on existing school buildings in a Pre-Alpine Region

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ABSTRACT

In this article we deal with the energy renovation of existing school buildings, one of the most relevant and current issue concerning Italian public buildings.

The necessity of a re-alignment with the European performance levels, achievable through a renovation of the school buildings stock, of which almost 90% is more than 30 years old, finds the two main obstacles in the lack of a full awareness of the current state of integrity of buildings and in the absence of an effective energy retrofit planning.

The aim of this study is to define the most promising renovation strategies applicable to all the school building in Lecco municipality, from both the economy and the energy point of view, through the development of an analysis method, repeatable and applicable to most realities, that allows optimizing and simplifying the energy analysis. The presented research is based on the classification and analysis of the study sample, consisting of 38 school buildings that differ in educational level, age of construction and typological design. The methodology developed allows dividing the sampled schools in homogeneous clusters, each one represented by a reference building, whose energy analysis makes it possible to define the best renovation strategy in terms of cost/benefit.

The results obtained provide replicable guidelines useful to the Public Administration in planning of energy retrofit interventions, in defining the total investment amounts and the consequent raising of necessary investments. Specifically the total investment would amount to € 62.971.530, with a calculated economic investment per student equal to € 5.060,0.

1. Introduction

For many years now the quality of the Italian school buildings has been in a state of emergency and it is far from many European countries quality standards; this issue is exasperated even more by the Public Administration lack of full knowledge on the matter of schools buildings conservation.

Nowadays the most complete and reliable research able to provide a representation, in broad terms and not in detail, of the current school buildings stock condition, is the report "Ecosistema Scuola" [1]; this is an annual survey on the school buildings quality, facilities and services that Legambiente has drawn up annually since 2000. This report submits an alarming picture about the 42,000 school buildings managed at the municipal and provincial levels, accommodating about 8 million students which represent over 15% of Italian population [2]: indeed more than 65% of schools were built before 1973, hence before Laws 373/1976 [3] and 64/1974 [4] became operative. In this scenario more than 39% of the buildings manifest an urgent need for maintenance and regulatory changes.

Furthermore, on taking into account the energy consumption, it emerges that the real situation is even more critical because about 90% of schools were built before the 1990's, and particularly before the coming to force of Law 10/1991 [5], which regulates the integration of energy saving measures and the use of renewable energies in buildings. The inadequacy and dated condition of the buildings, in conjunction with a greater environmental awareness, have led the Italian State to explore the issue and put forward sustainable restructuring interventions that are in line with the current European priorities. Moreover the international standard, in terms of energy efficiency in buildings [6], state the need to define strategies able to reach the Zero Energy Building target [7,8] for new and deep renovated building.

In this respect, the school building would represent an instance of successful sustainable architecture and would stand as a prime example of how the dual goal of preserving our cultural heritage, while promoting sustainable architecture, can be achieved.

The issue of this article is highly topical, as several studies demonstrate. Last year, in Austria the work of Stocker et al. [9]

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proposed a study about heating energy performance focusing on 8 different primary schools affected by particular climate conditions. The aim of their work regards cost-optimal building performance: they show that the best scenario is between a heating energy demand of 50–60 kWh/m^2 reach with different renovation strategies depending on building age and on energetic construction qualities. Similarly, Santamouris et al. [10] carried out energy audits on 238 Greek schools, characterized by an annual average total energy consumption amounting to 93 kWh/m^2. They prove that it is possible to reduce energy consumption by 20% with various energy-conservation strategies. The study of Trachte and De Herde [11], starting from the consideration that a lack of comfort has negative and scientifically proven consequences on pupils' concentration and learning, shows different energy efficient strategies for non-residential building. Also Dimoudi and Kosterala [12] focused on potential energy saving of school buildings in the climatic zone of Greece. They demonstrated, through simulation studies, that it is possible to reduce the heating consumption by 28,75% improving the insulation level. Sesana et al. developed and test a Methodology for Energy Efficient Building Refurbishment (MEEBR) on two case studies [13]. Another study was carried out by Desideri and Proietti [14] in order to calculate the energy consumption and the possible intervention to save energy in a school building stock located in Perugia, central Italy. The theme of improvement of energy performance in school building is assessed also by Dall'O' and Sarto [15]; starting from a study on 49 schools building located in the Lombardy region of Italy, they analysed cost-effectiveness building performance based on different energy retrofit scenarios. Their studies show that the excessive improvement of heating energy performance is not always the best economically advantageous solution. Butala and Novak [16], analysing a building stock of 24 school building in Slovenia, found that the heat loss in the sample was 89% higher than the recommended values. They assessed that the best cost-effective strategies, in 83% of the building stock, were through insulation of the envelope and replacement of windows. The energy renovation measure for existing building has been investigate also by Masera et al. [17] showing a set of innovative technologies for inner and outer envelope renovation. The importance of energy saving strategies and the improvement of energy performance in existing building is developed by the European Commission through the Commission Delegated Regulation (EU) n. 244/2012 [18]. The Commission proposes a comparative method to analyse the cost-effectiveness strategies for the existing building renovation by introducing a new instrument: a reference building. Its definition implies the study of a large amount of information, made possible by using the clustering analysis: a data mining technique that allows splitting the sample of buildings into small and homogeneous sub-groups. The analysis of each reference building, which is representative of its sub-group, allows extending the results to the other buildings in the cluster. This theme was carried out by many authors, such as Arambula Lara et al. [19], with the object of exploring a clustering method applied to a sample of 60 school buildings in the province of Treviso, North-East of Italy. They found out a few reference buildings representative of every cluster thus simplifying energy analysis. Similarly, Santamouris et al. [20], developing a clustering technique, selected 10 school buildings which were representative of a sample of 320 schools in Greece. They studied in detail the energy efficiency and the performance of the reference buildings proposing several scenarios in order to improve their energy behaviour. Some years later again in Greece, Gaitani et al. [21], starting from a sample of 1100 school buildings, which represents 33% of all secondary education schools, selected a typical building for each group, based on an energy classification, that they defined by means of clustering method.

The clustering method is a technique that can be used to analyse different types of buildings as demonstrated in many papers. For example, Petcharat et al. [22] applied this method to classify the energy performance of 36 case studies in Thailand. In another context, Heidarinejad et al. [23] used cluster analysis to examine simulated energy consumption of office buildings in USA. The main peculiarity of this work is that they apply the clustering on simulated buildings and not on real ones.

Through the achievement of a categorisation system and analysis of the current buildings integrity state, in order to create a knowledgeable database about the study sample, this work aims to define an analysis method, repeatable and applicable to different case studies. It allows the energy analysis to be optimized and simplified, with a view to determining the best renovation strategies applicable to every single school building, from both economy and energy point of view.

The final goal pursued is therefore to achieve a complete knowledge of the renovation strategies to be undertaken, of costs and benefits obtainable from each building, in order to carry out the most effective urban renovation planning.

The paper deals with the followings steps:

- Classification of the study sample through a mapping tool;
- Definition of the energy retrofit strategies, from both economy and performance point of view;
- Development of an analysis method, repeatable and applicable to most realities, in order to divide the sampled schools into more homogeneous and small groups, useful in terms of energy analysis;
- Determination of representative buildings for the purposes of optimizing and simplifying the energy analysis sample;
- Assessment of the most economically advantageous strategy for each cluster.

The proposed methodology can be extended to different context and to different building typology. Moreover, for each case, is necessary to know the type of building (eg. residential, tertiary or school building) and how they are occupied by the user in order to study the most promising renovation strategies. The proposed cataloguing form allow scheduling in a fast and homogenous way the geometrical and the qualitative characteristics of the buildings that represent the basis for the further retrofitting strategies analysis.

The main weak point is represented by a lacking of information regarding the building characteristics (drawing, energy certification, building technology etc.) from which derive the information for the building classification. The impact of work is definitely considerable if conducted using informatics' tools that share information in a single database accessible to a large scale of users.

Considering the information flow the following Fig. 1 shows the relation

2. The Italian local school building stock: analysis

2.1. General description

As of 1996 with the coming into force of Law 23/1996 [24], a special interest in the Italian school buildings stock began, which ensured a targeted planning of the interventions with the aim to achieve a better qualitative development.

Through the above mentioned law, the MIUR (Ministero della Istruzione Università e Ricerca) [25] (Ministry for University Education and Research) engaged in the realisation and the development of a National School Buildings Mapping upgrade; this computerised and cognitive tool would allow assessing the consistency, the condition and the availability of the existing school buildings stock on the national territory, in order to improve the effectiveness of the programming activities of maintenance and requalification.