385: School buildings as learning tools: guidelines for the eco-efficient renovation project

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Abstract

The need to renovate existing school buildings – characterised by physical, functional and normative problems – offers an opportunity to improve the technological and environmental performance of assets with a strong symbolic value. Insofar as they are public buildings and, as such, reflect the community to which they belong, schools can be considered not only material but also educational and social assets, ideal places for spreading a culture based on the principles of sustainability.
The main aim of the research is to identify criteria, addressing public administrations, designers and final users, able to guide technological-environmental renovation of existing school buildings, with particular reference to two major aspects:
- building eco- efficiency
- management eco-efficiency

related to the need of reduction of the environmental load, rational use of resources and users' comfort and health.
The results of the research include: a simplified auto-evaluation method based on the UNI approach to assessing building ecocompatibility, adapted to existing school buildings, that can be adopted directly by the public administrations for quality control of the environmental performance of their buildings; guidelines that indicate solutions and strategies for the renovation of school buildings and for aware management of these, addressing not only local authorities but also the various users of the school.

Keywords: sustainable school renovation, building eco-efficiency, management eco-efficiency

1. Introduction

The ecocompatibility of school buildings is a matter of growing interest. In addition to being a material heritage, schools are educative and social assets, ideal places for spreading a culture based on the environmental approach. A sustainable change in behaviour patterns, that must pass itself on to the whole of the population, proceeds through information, education and the features of the environment in which one grows up. The quality of a school - the environment in which most of the day is spent from childhood - spontaneously creates an awareness of the logic involved in the rational use of energy, water and raw materials, and in reduction of the production of wastes and their separate collection.
The topicality of these considerations is being increasingly recognised in the designing and construction of new schools. Their application to existing schools is a more complicated question, one that is recognised internationally and concerns, especially in countries such as Italy, a substantial share of the total stock.
This paper presents the initial results of a research directed to the identification of criteria for the sustainable architectural and managerial renovation of existing schools.
The paper is divided into four parts. The first illustrates the national and international reference background. This outline of the ambit of the survey is followed in the second part by an indication of the objectives of the research. The third part illustrates the method employed and the main phases of the work. The last part sets out the results obtained in the identification of indicators to be used in the evaluation of existing school buildings and guidelines for ecocompatible improvement measures. Moreover, this part illustrates the first application of the tool, with initial case studies and results.

2. Reference background

2.1 Europe and the environmental approach to school building

Many European countries, particularly in the centre and north of the continent, are applying shared measures for the ecocompatible designing of schools in terms of the rational use of resources, and reduction of the consumption of energy from fossil fuels and the emission of pollutants.
The need for a substantial change in the ways of building, managing and maintaining school buildings is underscored by the interest displayed by the European Union (EU) and its Member States in the activation of specific school renovation programmes. Programmes such as

"Check it out!" [1] funded by the EU, or *"Eco - schools"* [2] promoted at the international level, are designed for the assessment and improvement of the energetic and environmental performance of existing school buildings. They comprise important pedagogic elements and directly involve users through participative processes. Through their approach to various bearers of interest in school communities, they constitute an excellent tool for the local implementation of sustainability policies (i.e. Agenda 21).

2.2 The problem of school building renovation in Italy

The quality of Italian school buildings is very often insufficient in technological, functional and normative terms. Recent research work has shown that many buildings, especially those erected between 1960 and 1990, are no longer able to meet the needs of their users, nor, in the wider sphere, the sustainability objectives envisaged in the international political agenda.

Emblematic in this respect are the published results of Italy's main survey known as *"Ecosistema Scuola"* [3]. This is carried out annually by Legambiente on 42,000 buildings managed by municipalities (compulsory schools) and provinces (higher education institutions). Data supplied by the local authorities on questionnaires are collected and processed to create a guiding overview of the quality of the structures, services offered and good environmental practices, as well as the risks to which users of schools are exposed. The situation that is emerging clearly shows that the maintenance of Italian school buildings is a matter of urgency, and that less than 50% have been attended to during the last five years. Even so, the dossier, in addition to illustrating the state of emergency, indicates that renewal in the direction of sustainability is possible. There is an improved awareness of the question of consumption. Separate waste collection is increasing along with investment in renewable sources of energy and other forms of energy saving.

3. Objectives

Greater sensitivity towards environmental topics on the part of local authorities, on the one hand, and the introduction of new financial instruments for school buildings and the sustainable management of schools, on the other, are influencing the policies of local agencies, both in Italy, albeit with a certain delay, and the rest of Europe.

The general aim of the research is to identify criteria for the technological and environmental upgrading of existing schools with a view to their improvement in terms of ecocompatibility, and to incentivate and promote sustainable recovery practices.

Particular attention is being directed to Italian schools built between 1960 and 1990, though the objectives, methods and results can equally be adopted in other countries.

Two specific aims have been pursued:

1. preparation of a list of simplified indicators with which to structure evaluation of the present state of these schools with regard to ecocompatibility requirements;
2. elaboration of guidelines suggesting, where necessary, technical-designing and/or theoretical-procedural solutions for their renovation.

These indicators are systematically directed to characterisation of a simple auto-evaluation method to be used by public administrators to check the quality of the environmental performance of their buildings, in other words a tool to be employed to:

- identify the most critical buildings, the evaluator being the subject handling the programming of the maintenance measures;
- form the basic diagnostic picture needed for any subsequent quantitative assessment;
- prepare a census of the building and mechanical installation technologies, and a large-scale monitorial survey of energy consumption in school buildings, in function, inter alia, of the intended compilation of a national School Buildings Register from the data to be collected. This has not yet been prepared, but should provide updated information concerning the state of school buildings.

Once the critical situations are determined, the guidelines will complete the picture needed by local authorities to define the specifications and advantages of any future operations, and suggest also strategies directed to end-users. The guidelines are an integral part of the method adopted with a view to raising consciousness and awareness of technological and environmental issues.

4. Method and phases

The analytical and procedural approach adopted in the research has been implemented in three stages:

a) identification of recurrent problems in existing school buildings, and their possible solutions through the evaluation of some case studies;

b) analysis and comparison of current score-based, school building assessment methods;

c) arrangement of a series of indicators in accordance with the needs-and-performance approach adopted by the UNI standard entitled *"Sustainability in Building"*.

4.1 Identification of recurrent problems and possible solutions: case studies

Evaluation of the performance of some sample school buildings has revealed a series of recurrently critical architectonic and mechanical equipment features. It has also provided a picture of energy consumption, emission of greenhouse gases, and environmental comfort, and led to the elaboration of energy upgrading solutions open to

adoption by other schools.
The reference sample was chosen in response to a request from the Municipality of Moncalieri, near Turin (Italy), for advice on how to set about the technological and environmental renovation of its schools. The DINSE department of the Turin Polytechnic, in fact, was commissioned to examine the possibilities of employing renewable sources of energy in the schools erected between 1970 and the mid-1980s (regarded as the most problematic), and their energy improvement. The technological and construction features of the schools involved in this research [4] thus represented the most recurrent situations insofar as about 30% of all the schools in Italy were built in this period [3].

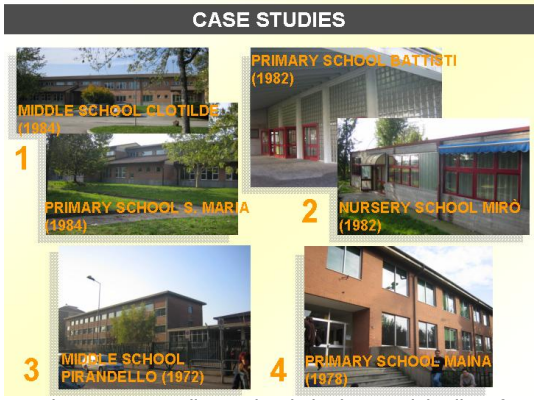
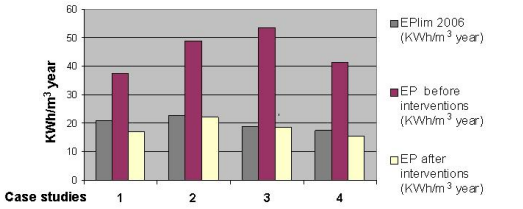


Fig 1. Case studies: schools in the Municipality of Moncalieri chosen because they were problematic in terms of energy efficiency, and also representative of the most recurrent building technologies.

The steps taken comprised geometrical and technological surveys of the buildings, examination of the technical and consumption documentation, and visual inspection and coring of the walls to determine their stratigraphies. The calculation method adopted for the evaluation was drawn from the UNI standards and the current legislation.
Assessment of these buildings disclosed the inadequacy of both the single components of their envelope (high transmittance values of walls, windows, roofs, floors facing unheated rooms or the outside), and their overall energy performance (envelope and mechanical systems) with respect to the limits laid down by Legislative Order No. 311 of 2006 (issued in application of EC Directive 2002/91 on energy efficiency in building), with consequent effects on energy consumption, emission of greenhouse gases, and environmental comfort.
The measures proposed take account of their technical feasibility, the defective performance of the single stratigraphies, the level of obsolescence of the buildings and their parts, and the benefits expected from their management (in terms of energy saving and CO_2 emissions avoided). The per cent reduction of primary energy requirements after such measures is influenced by the technological specifications of each building, since they obviously confer less benefit on younger schools or those that have been recently maintained.



School	Construction year	EPlim 2006 (KWh/m^3 year)	EPlim 2008 (KWh/m^3 year)	EPlim 2010 (KWh/m^3 year)	EP before interventions (KWh/m^3 year)	EP after interventions (KWh/m^3 year)	improvement after interventions (%)
1. Clotilde / S. Maria	1984	20.93	18.46	16.18	37.4	16.87	55%
2. Battisti / Mirò	1982	22.69	19.98	17.46	48.66	22.1	55%
3. Pirandello	1972	18.75	16.59	14.6	53.52	18.61	65%
4. Maina	1978	17.24	15.29	13.5	41.27	15.38	63%

Fig 2. Comparison of the energy performance (EP) index values before and after the intervention measures with respect to the limit values (EPlim) laid down by Legislative Order No. 311 of 2006, issued in application of EC Directive 2002/91 on energy efficiency in building.

The following main ways of securing an advantageous retrofit that solves the problems that have emerged thus involve both the technological system of a building and its energy management:

- improvement of the performance of the envelope (more thermal insulation, replacement of windows, installation of suitable sun screens);
- replacement of obsolete components in lighting and HVAC systems with others that are more energy-efficient and more environment-friendly in terms of their emissions;
- employment of energy-saving lighting and climate control devices;
- utilisation of the sun's free energy to produce energy from photovoltaic panels and heat from solar collectors;
- correct management of natural ventilation and passive cooling to limit the resort to the summer air conditioning systems responsible for a heavy consumption of electricity;
- in general, information, training and making users ready to adopt more sensitive and conscious behaviour patterns and save resources.

4.2 Examination of current school buildings assessment methods

Detection of the most frequent critical situations has been followed by examination and comparison of some score-based evaluation methods in order to draw up a list of the indicators needed to assess a specific form of use, such as a school. Reference has been made to the most consolidated methods for evaluating the technological and environmental efficiency of school buildings, namely CHPS and LEED in the United States, BREEAM in the United Kingdom, and Protocol ITACA in Italy.
CHPS (Collaborative for High Performance Schools) [5] has been set up by a series of governments, industrial firms and American non-

profit organisations to facilitate the designing, construction and maintenance of eco-efficient schools. *LEED for schools* (Leadership in Energy and Environmental Design) [6] has been elaborated by the U.S. Green Building Council: it identifies indicators for assessment of the ecocompatibility of new school projects. *BREEAM Schools* [7], devised by the BRE research centres, is also devoted to newly erected school buildings. *Protocol ITACA for assessment of the environmental sustainability of school buildings* [8] is an adaptation of the corresponding Protocol for residential buildings. It is the only method that can be used to assess the compliance of existing school buildings with the eco-efficiency requirements. It was elaborated by ITACA (Istituto per l'innovazione e la trasparenza degli appalti e per la compatibilità ambientale) in response to an announcement by the Piedmont Region for the granting of contributions towards measures for the renovation of school buildings.
Comparison of these eco-tools has been undertaken with particular regard to the specific evaluation areas, the type of indicators considered, and the checking method employed.
Crossing of the most recurrent problems revealed by the case studies with this type of analysis has resulted in the adaptation and integration of some indicators (generally studied in these tools for the construction of new schools) for the evaluation of existing school buildings.

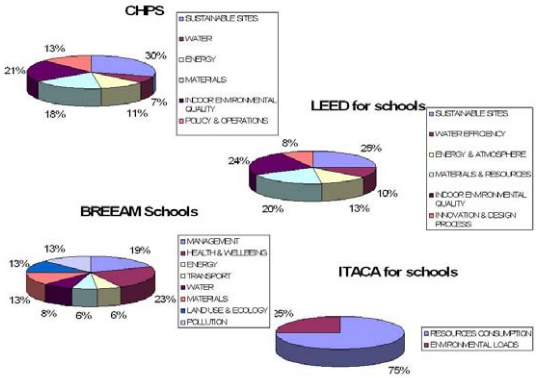


Fig 3. Indicators used in the four evaluation methods and their respective per cent incidences.

4.3 Organisation of indicators

It was decided to employ the needs-and-performance approach adopted by the UNI standard (National Association for Standardisation) entitled *"Sustainability in Building"* to organise the indicators as opposed to the categories typical of many eco-tools whereby indicators are directly associated with thematic areas.
This standard has been devised by Working Group 4 of the UNI Building Process Commission. It identifies the ecocompatibility needs and requirements of building projects in function of individual stages in the building's life cycle. The indicators thus identified refer to three needs: reduction of the environmental load, rational use of resources, comfort and health during the building's use and operation stage.

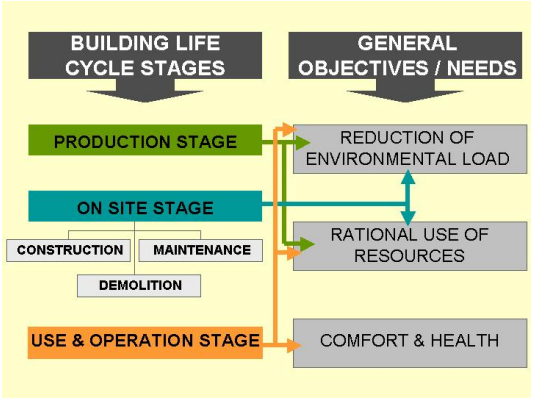


Fig 4. The reference needs in the UNI "Sustainability in Building" standard.

5. A tool for auto-evaluation of the eco-efficiency of school buildings

5.1 General structure

The auto-evaluation tool is composed of three sections. The first relates to a form on which the general information concerning a school is filled in: name, address and number of sections, building date, ground plan and volume data, construction technology, type of mechanical systems, and energy and water consumption data.
The second section comprises the indicator forms. These set out the (usually qualitative) criteria for evaluation of the present state of school buildings.
The third section contains the guidelines for the intervention measures.

5.2 The indicator forms

These are the core of the evaluation process. They are directed to the checking of two features:

A. BUILDING ECO-EFFICIENCY: assessment of the physical characteristics of a building, namely its materials, elements, components and mechanical systems, and its site.

B. MANAGEMENT ECO-EFFICIENCY: evaluation of the features associated with the behaviour patterns employed by the users of a school (public administrators, teachers, staff) in its conscious management and in the environment policies implemented at the institute level.

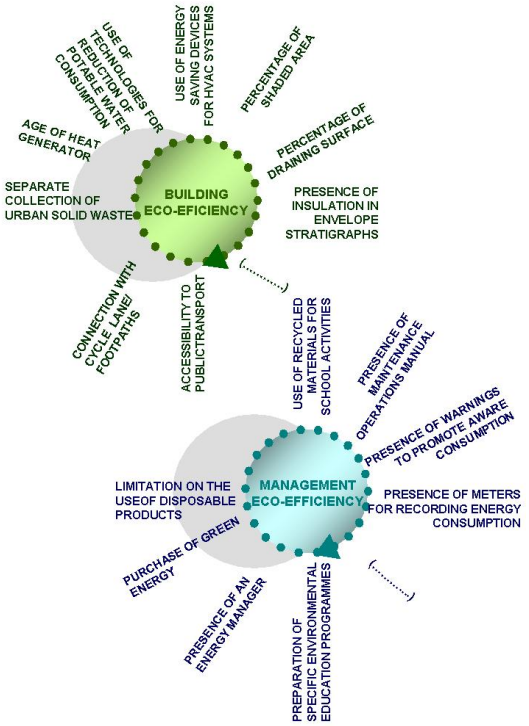


Fig 6. Examples of the indicators used to evaluate the two eco-efficiency features.

The first section of each form sets out information relating to: the *evaluation area*, i.e. whether building eco-efficiency or management eco-efficiency is to be assessed, the *need* (general objective) and the reference *requirement* according to the approach adopted by the UNI standard cited in paragraph 4.3, the definition of the *application field*, i.e. whether the reference scale is the site, the building or individual environment units. The middle of the form sets out the *name of the indicator* and the relative *evaluation method*. The last part lists the *bibliography* from which the checking method is derived and the *references to the guidelines* (category and title of the action) to be followed if the indicator is not verified.

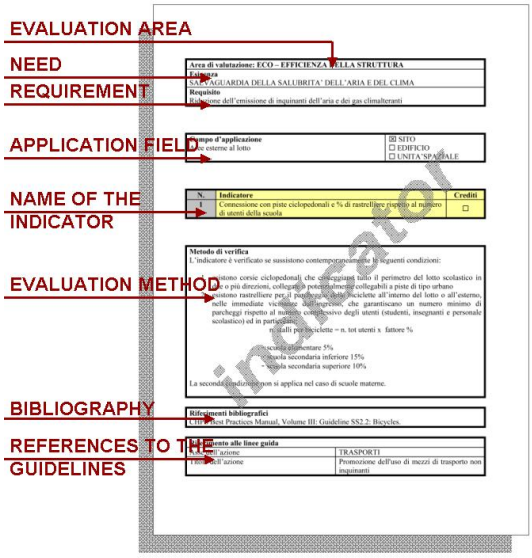


Fig 7. Structure of an indicator form.

5.3 Evaluation method

The evaluation method does not yet comprise a weighting system, which means all the indicators have the same value. This is because the main aim is to identify the requirements that are not met and for which remedial measures can be undertaken. Determination of most critical aspects and the priority of their correction is left to the local authorities to decide in the light of their objectives and the budget available.

Evaluation by means of a checklist is used to assign an overall ecocompatibility score to a school so that it can then be compared with others.

This simple form can be readily filled in by non-specialised evaluators, both local authority officers and the end-users of the school.

Teaching programmes enable students, with the help of their teachers, to become familiar with their school's environmental problems, and acquire an ecological consciousness of their day-to-day surroundings that will result in the adoption of more sustainable behaviour patterns.

5.4 The guidelines forms

Each indicator is accompanied by guidelines that provide technical and design improvement solutions for the local authorities, engineers and professionals, and/or theoretical and procedural solutions for those who use the school.

The top part of a typical guidelines form states the indicator to which it refers. The remainder consists of: the *category* (the general thematic area), the *title of the action* (its name), the *objective* (its purpose and aim), the *kind of action* (technical and design, or theoretical and procedural), the *characteristics of the action* (its particular features and the ways in which objective is to be attained), the *applicability of the action* (the cases in which it is or is not valid and can or cannot be adopted), the *advantages* (the benefits the action will provide), and the *normative references* (the relevant legislation and the standards to be used in the application of the action).

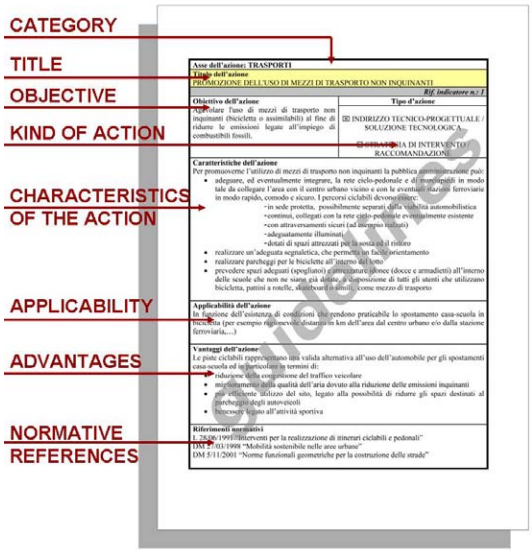


Fig 8. Structure of a guidelines form.

6. Application of the tool: case studies and initial results

Assessment of the efficacy of the auto-evaluation tool thus elaborated will be undertaken though its application to 14 primary and 3 secondary schools maintained by the Municipality of Moncalieri, near Turin, divided in accordance with their construction dates (1960-1970, 1980s and 1990s), and classed as light, average or heavy buildings. Nursery schools have been excluded for the moment to enable an idea to be gleaned of how many schools directly involve their pupils and teachers in filling in the evaluation forms.

These forms will be accompanied by a *post-evaluation questionnaire* to be filled in and returned with information concerning: the person who filled in the form (school director, pupil, teacher, member of the Municipality's technical staff, others); the number of hours required for the evaluation; the school's score; the indicators best able to illustrate the school's problems; other problems relating to the school building or its management, but not brought out by the evaluation; an assessment of the guidelines as sufficient, insufficient or good with respect to the indications they provide for the solution of problems.

In the meantime, the first test made reference to all the data contained in the case studies for the schools comprised in the contract between the Municipality and the Turin Polytechnic's DINSE department (see section 4.1). The albeit partial picture that emerged has enabled some comments to be advanced concerning the schools themselves and the auto-evaluation tool.

The very low scores obtained by the schools as a whole emphasise their inadequacy in terms of the ecocompatibilty criteria; the best result, in fact, conformed to only 14 the 50 indicators. Generally speaking, the most critical features are those relating to the eco-efficiency of a school's management: no more than one or two indicators per school were met out of the 20 comprised in this section of the tool, though it must be added that these few referred to "Quality of the educational project", and thus denoted a trend towards the arousing of consciousness, the provision of information, and the instruction of users in environmental issues thanks to specific programmes teaching the responsible employment of resources that foster awareness in a person's in-school and out-of-school lifestyles. The structural eco-efficiency features that brought down the final scores were assignable to various unsatisfied needs, from the rational use of resources to the comfort and health of users in relation to the specifications of a school's envelope and mechanical equipments.

It was found that the results obtained with the auto-evaluation tool were congruent with the previous diagnoses and energy assessments. Moreover, the easy interpretation of the evaluation form was illustrated by the relatively short times needed to fill it in: it is expected about a couple of hours on the part of the technical staff, and from 8 to 10 hours for the pupils guided by their teachers.

It is expected that the forthcoming results will yield critical subjective assessments of the tool, leading to a fuller understanding of its limits and potential.

7. Conclusions

The need to renovate schools provides an opportunity for reflection on the profound necessity to confer a "renewed quality" on obsolescent buildings, namely public buildings and as such representative of the community to which they belong, and require adjustment to higher performance standards so as to safeguard the environment and human health and well-being.

The advantages of an auto-evaluation tool such as that identified here stem from its simplicity and immediacy, features that enable it to be used by a variety of subjects: by local authority officers for qualitative assessment of the state of health of their buildings and the need for remedial measures, by teachers and students as a didactic and cultural project, and by designers as the initial source of the indications from which to elaborate a renovation project. The indicators and guidelines are devoid of any geographical references and can thus be adopted outside Italy.

The present limitations of the tool stem from the need to put it to the test in a significant number of cases.

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