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BEEPS (BUILDING ENERGY & ENVIRONMENT PERFORMANCE SYSTEM): A PROGRAMME FOR ITALY

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ABSTRACT

The objective of the paper is to promote a tool related to the improvement of the energy performance of buildings in Italy, taking into account climatic conditions, as well as indoor environment requirements and cost-effectiveness. The programme is performed by Italian Ministry of Environment and Department of Fisica Tecnica of the University La Sapienza of Rome and the aim is to prepare for the compliance with the EU Directive on building energy performance.
The programme consists in two stages. The first stage is a self-assessment of existing buildings available on-line (www.beeps.it) for a first simplified evaluation by means of a questionnaire coupled with a call-centre technical support, and a second stage is a further detailed assessment for new building and for the existing ones which have not match the first self-assessment target. The code will take into account different weighted parameters, such as: building envelope, energy consumptions, indoor environment quality, and other aspects such as: materials, economics, environmental impact are also considered. Residential premises and winter season have been considered at this stage. The procedure has been validated over more than 120 case-studies related to residential real estate in Rome.
The software BEEPS (Building Environment and Energy Performance System) uses an expert system (by means a self-learned system and a Geographical Information System tool).

INTRODUCTION

The percentage of some 40% of the 930 Mtoe of EU energy consumption is used in the residential and tertiary sector. In this sector, it is possible to reduce the energy demand by an active regulation policy which may lead to a better control of the final use of energy. In residential buildings almost 60% of the final use of energy is related to heating or air conditioning, and 25 % to water heating.
The study presented would like to be a test procedure in the frame of the activity program on building energy performance carried out officially in Italy by UNI-CTI which is responsible to develop technical Standards in Italy. Following an official European Directive [1] to express essential requirements in a performance-based building strategy, a programme for developing a performance assessment of buildings, consisting in two stages, have to be launched. The aim of the study is to prepare for the compliance with the EU Directive on building energy performance, matching the EU actions to get:

- a reduction of the CO_2 emissions
- a waste minimisation
- a prevention of the indoor air pollution

Studies concerning other characteristics of the tool are presented elsewhere [2], [3].
The UNI-CTI proposal is based on the use of two existing Technical Standards coupled with two Technical Reports TRs, in order to evaluate the primary energy consumption of a building:

- Calculation of the energy demand of the building envelope, based on an existing Standard UNI EN 832 and a coming TR which defines the input data for calculation procedure UNI EN 832.
- Calculation of primary energy and building services efficiencies, based on an existing Standard UNI 10348 [4] and a new TR which defines the input data for calculation procedure of UNI 10348 and in particular: input data for heating systems, hot water consumptions and efficiencies of heating systems, actual consumptions audit procedure.

THE CERTIFICATE “BEEPS”

Figure 1 shows the general scheme for the procedure adopted in BEEPS. It presents 5 different evaluations related respectively to: (1) building envelope, (2) building services, (3) indoor environmental quality (IEQ), (4) use of renewable energy (including passive use of the building), (5) material and installations life cycle analyses, presently being implemented three (#1, #2, #3) out of the latter five votes.
The building performance includes residential premises during the heating season.
The building performance starts by compiling a simplified friendly users evaluation questionnaire which consists in 5 different forms to be filled on-line (www.beeps.it).
The certificate can be obtained via internet after the compilation by the owner of five forms in order to insert data regarding each single flat and its heating season in five different modules in which the collection of the information has been structured.
Data are requested for any single flat, being the expert system able to recognize flats belonging to the same building (see later).
Input data are collected in 4 groups::

- General information (IG): They identify the location and the typology of the building (8 questions).
- Building Information (IE): They identify the year of construction, the geometrical and surfaces data of the buildings (4 questions).
- Information about the apartment (IU): envelope surfaces and their exposure, materials, number and typology of retrofitting.
  Presently BEEPS program doesn’t allow a final evaluation is the following limits have not been matched:
  - Floor surface for apartment <= 300 m^2;
  - Number of windows for each exposure <= 10;
  - Number of floors for each apartment <=2;
  - Number of persons for each apartment <=8;
  - Electrical bill <=50 Euro/m^2 year;
  - Thermal bill <=100 Euro/m^2 year.
- Plant Information (II): One years of energy management has to be mentioned by means of electrical and thermal bills, the latter being split into heating and hot water production systems.
- Information about Indoor Environment Quality (IEQ): One of the topic to be considered from EC Directive is the prevention from indoor pollution. The IEQ evaluation can be derived by a series of questions about acceptability of indoor environment under consideration, [5], [6]. The novel feature of the questionnaire which collects information from the end-users, is a double Likert scale for liking and importance of a number of factors relating to indoor environment and management. Related to each interview (name, surface and volume, year of construction and restoration, materials and their state of conservation, occupancy), the following factors are considered: noise level, lighting, daylight, temperature, ventilation IAQ, humidity, management & maintenance.

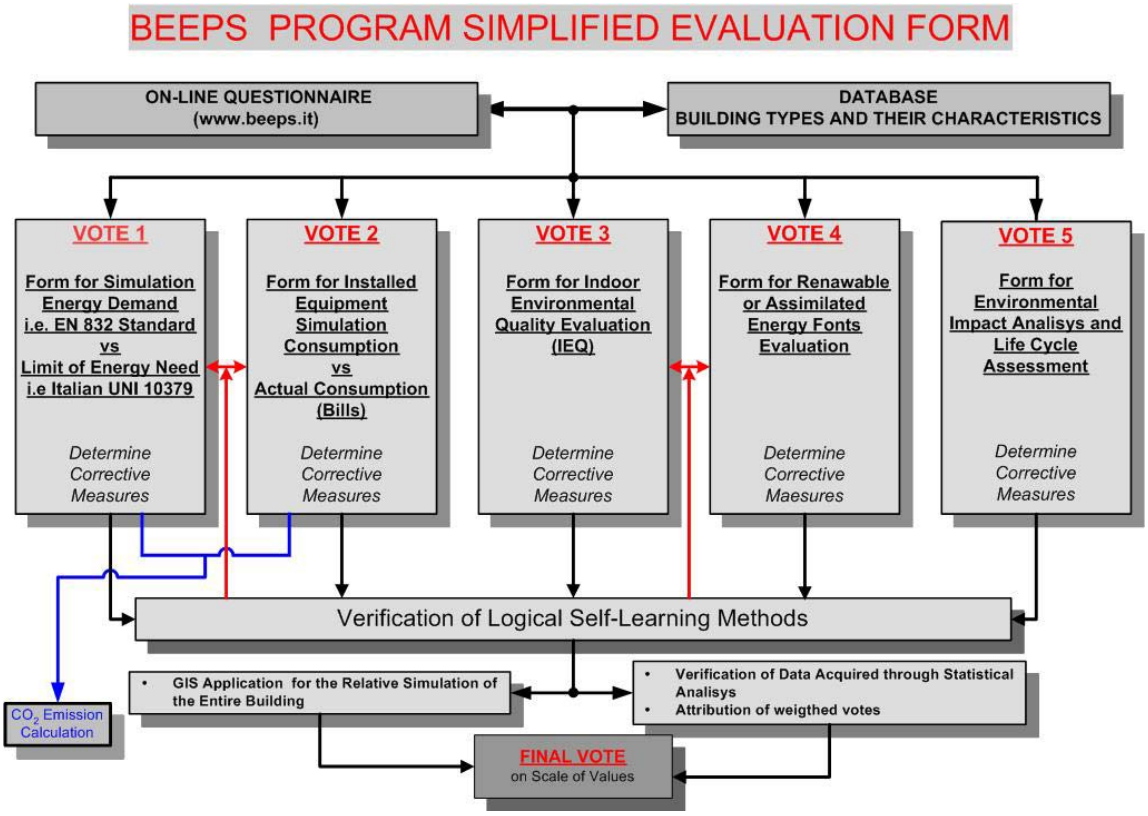

Figure 1 – Flow-chart of the BEEPS procedure

Compilation of questionnaire could also be performed by non-expert users. Starting from the user's answers, 5 votes are selected, following the numerical scale:

- From 0 to 0,99: poor;
- From 1 to 1,99: insufficient;
- From 2 to 2,99: acceptable;
- From 3 to 3,99: good;
- From 4 to 5: excellent.

Final votes represent the synthesis of the evaluation procedure and doesn't express a mere qualitative judgment: any numerical vote is generated by BEEPS by means of algorithms and after the attribution of different weights, a final vote could also be expressed.

The rating related to the building envelope is calculated by:

$$V1 = \frac{E_{calc} - E_{\lim}}{E_{calc}}$$

in a 0-5 range vote, where E_{calc} is obtained automatically by applying EN832 and E_{lim} is the limit-value (*FENlim*) imposed by Italian Standards for building energy consumption (UNI 10344).
The rating related to the building services is calculated by:

$$V2 = \frac{E_{BILL} - \frac{E_{calc}}{\eta_m}}{E_{BILL}}$$

in a 0-5 range vote, where E_{BILL} is obtained from thermal energy bill and η_m is the seasonal efficiency of production system (calculated, for example, applying UNI 10344).
The vote V3 related to IEQ is obtained applying the procedure presented in [5], [6].
From the IEQ questionnaire a fingerprint and score can be derived. The individual liking score ILS for the individual form (any single apartment) is the average of all the multiplications normalised by dividing by the

maximum possible score and expressing as a percentage; the group *overall liking score*, OLS, is the average of the ILS's for the group (constitutes by each apartment).
In addition to the liking score, the individual factor scores (FLSs), can be shown as a fingerprint for each of the parameters considered. The factors have been ranked for ease of viewing.
The procedure allows to obtain three sub-groups evaluations: Acoustics and Visual Comfort (BAV), Thermal Comfort (CTI), Ventilation Comfort (VENT) which afterward by applying weighted factors are combined together.
The votes V4 (use of renewable energy) and V5 (material and services LCA) are presently submitted to a further evaluation, see also [7], [8], [9].
The section "Votes" on the net is graphically represented by a diagram which reports V1, V2, V3 (see Figure 2) coupled with a text which summarizes energy consumptions and CO_2 releases (see Figure 3).

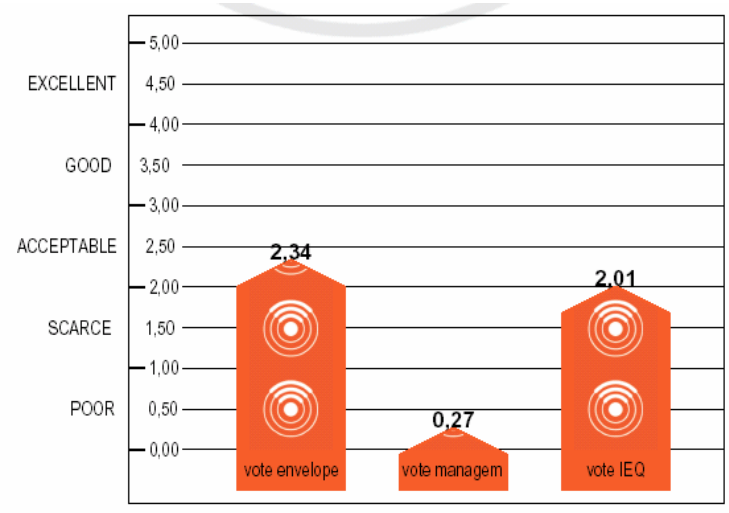

Figure 2 – Output of BEEPS procedure: V1, V2 and V3.

Figure 3 – Evaluation results

THE EXPERT SYSTEM FOR THE EVALUATION IN TEXTUAL FORM

The energy certification must supply useful information regarding the energy performance of the building also in sight of the sale/purchase of the building and it must also indicate a list of possible necessary interventions in order to promote the improvement of the energy performance of the building in question. Such a list of interventions must cover the building envelope and installation system as a whole taking into consideration the installed equipment during the phase of installation as well as during the management phase, and it may include energy savings projects that, in the case where it is limited to the public sector, can be completed by financial studies (financial projects).
A text concerning the final evaluation of the building (see Figure 4) is shown in the certificate.
This first stage is a self-assessment of existing buildings for a draft simplified evaluation, but a second further detailed assessment stage is strongly suggested for the buildings which have not match the first self-assessment target.

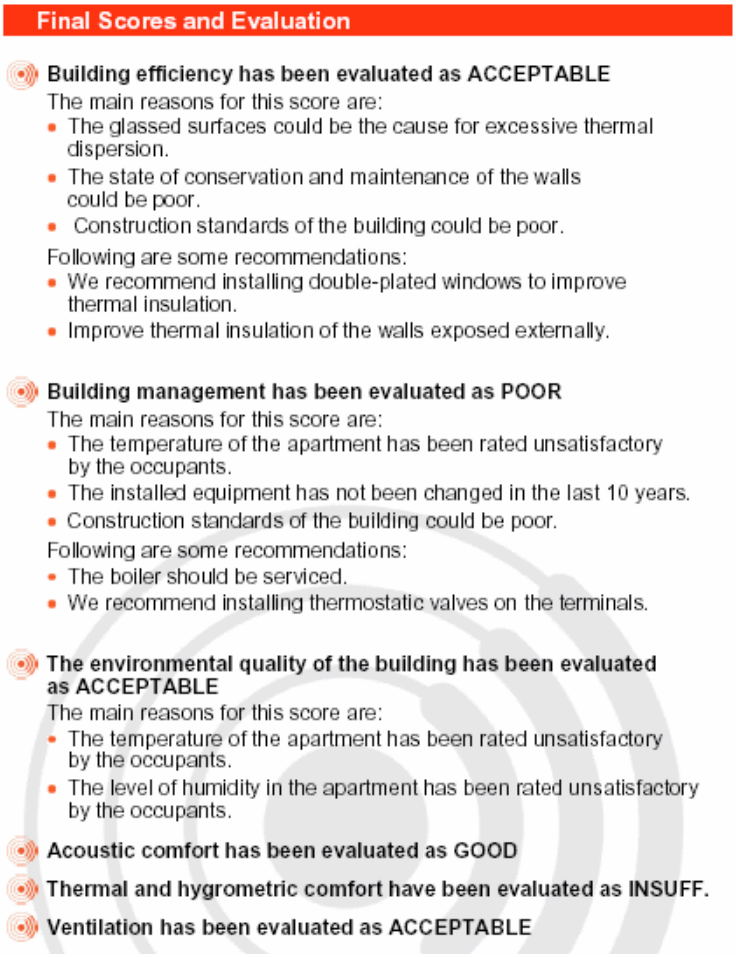

Figure 4 – Final evaluation in a text-form

An Expert System has been designed and realized in the framework of the Beeps project to provide information in a friendly and readily usable form. The scope of such system is twofold: one the one hand, it produces a very easy-to-understand explanation of the votes that have been computed by the other modules of the beeps system; on the other hand, it can elaborate in an independent way additional knowledge, different from the one used in the other modules. The peculiarity of this module is to be found in the fact that it uses a system of logic rules that can be easily accessed, modified, and updated by the experts that maintain the system. Once the knowledge has been modified, the reasoning model will take the new knowledge into account in its reasoning, without the need of additional technical expertise related to the computational aspects of the system. The final outcome of the expert system is a body of text that resembles the evaluation of a human expert based on the available knowledge, that can be read and understood by people with no particular technical background.
Further information about the expert system used in BEEPS programme can be found in [3].

GIS APPLICATION FOR THE BUILDING ENERGY PERFORMANCE

The GIS Geographical Information System represents an important instrument in order to elaborate data processed in BEEPS methodology. GIS is a system of computer software, hardware and data to help manipulate, analyze and present information that is tied to a spatial location. It generates a calculation procedure which, starting from a limited number of flats of a same building, is able to characterize the behavior of the building as itself. GIS application diagram is shown in Figure 5, [10].

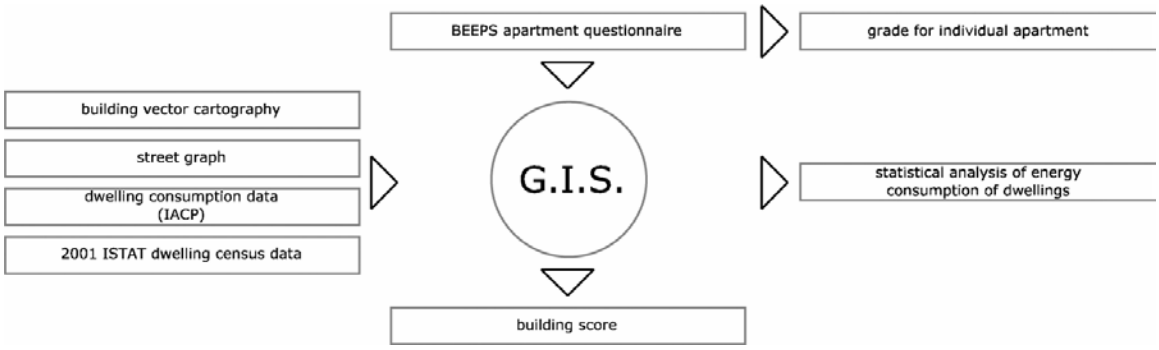

Figure 5 – GIS application diagram for building energy performance

The tool provides to combine data from many sources. Digital archives supply all the information needed by the GIS in order to reach the building score. By means of the resources of different codes it is possible to link and relate multiple data bases and elaborate information related to any single building. The procedure is based on geographical data of the area of Rome, dwelling construction data (all the building analyzed are council houses managed by an Institution which is the owner of such a real estate, i.e. IACP). The Institution gives also further information about building construction typology and energy annual bills.
Further information about GIS application in BEEPS program can be found in [3].
The analyzed buildings contain 30 flats as an average, but it is sufficient to process data related to only limited number of cases to simulate the behavior of the building associated, remaining in the same order of magnitude of the simplified energy calculation error. In Figure 6 are reported the results coming from the GIS application in the BEEPS procedure; they represent the comparison between actual vs calculate energy consumptions as a function of a buildings analyzed. It can easily be seen that by processing more than 40-50 % of the flats in a certain building the error obtained is under 20%.

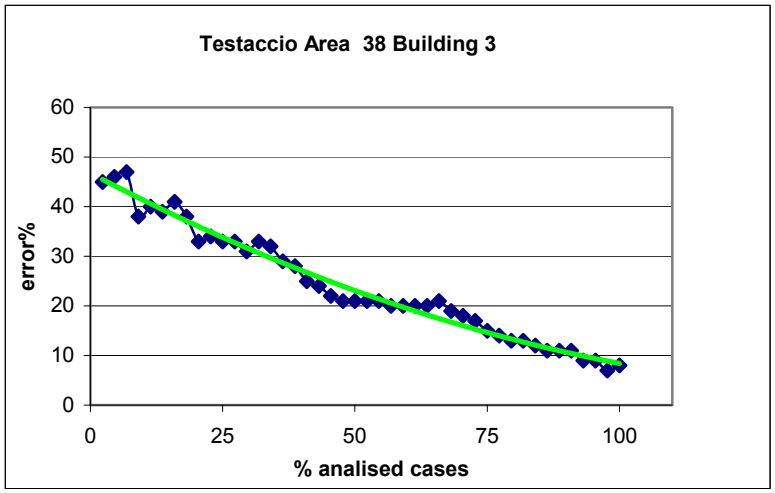

Figure 6 – Errors in the evaluation of the energy consumptions in a building as a function of its flats

CONCLUSIONS AND FURTHER DEVELOPMENTS

The Database implemented in the program BEEPS is presently related to typical residential real estate in Rome, with the following features.
The building structures follows the local typology evolution of the building sector which can roughly be related to three historical periods to identify the structures related to all the technical elements of the building (i.e. materials, fenestrations, etc.):

- I- up to 1910, with the presence of wall carrying structure realized with different technologies
- II- from 1910 to 1970, where wall carrying structure and reinforced concrete are often joint together
- A further subdivision of the period (1910 - 1945 and 1946 - 1970) should include more information about the prefabrication

- III- after 1970, where reinforced concrete structure result predominant, characterized by a closure non carrying exterior walls.

The archive of real estate of IACP property can also be extended to other activity than energy performance of buildings, such as the building management and its seismic prevention. Systematic connection between building management and energy efficiency is welcomed particularly in the case of public premises.
The procedure – now automatically executed for the residential sector of Rome - can be easily extended to other Italian towns, by modifying the typology of constructions and climatic data.
The results of 120 case studies of residential real estate in Rome are presented in Figure 7 where the frequency distribution of V1 and V2 is reported, while in Table I are summarized CO_2 emissions per square meter and year and the average values for votes and consumptions.

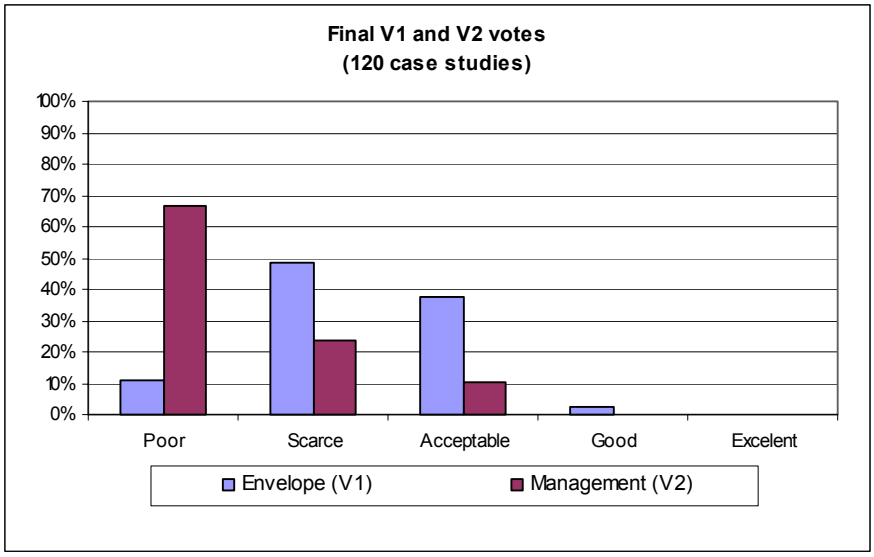

Figure 7 – Frequency distribution for the V1 and V2 referred to 120 case-studies

Average values (120 flats)				
Surface (m^2)	V1 BEEPS Building Envelope	V2 BEEPS Plant management	CO_2 emission (kg/m^3/year)	Consumptions (kWh/m^2/year)
58	1.84	0.78	13.03	133.71

Table I

Further developments of the study will regard:

- The addiction of V4 (renewable energy and passive use of building) and V5 (Life Cycle Assessment LCA);
- The extension of the assessment to the summer season and to the third sector buildings;
- The extension of the procedure to all the building by means an appropriate data base (requested on-line) which collects geometrical and thermo-physical parameters of the building, as well as climatic data.

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