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DECISIONAL PROBLEMS IN THE BUILDING PROCESS. CONTEXTUAL EVALUATION OF PERFORMANCE AND COST PARAMETERS: BEASONER 'C' IN THE CASTORP SYSTEM.

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Abstract

The study contains the provisional results of investigations currently in progress on the application of CAD and Design Management techniques to building design.
The research aims at showing the feasibility of decisional procedures and economic analyses in current design practice, even referring to rather complex buildings, by exploring the possibility to know in full detail the technical and economic feasibility of a project already at its early stages.

0. Foreword

A preliminary hypothesis for the implementation of an expert system for building design has already been put forward in [2]. A series of 'reasoners' capable of carrying out a series of intelligent operations that are regarded as typical of building design has, been proposed. As already said in [2], some experiments on three typologies of reasoners are currently under way at the Istituto di Edilizia of the Engineering Faculty, Ancona.
Reasoner 'A' tackles the problem of placing objects within a pre-defined space. It has an analogical representation of space and uses 'fuzzy logic' [5] to represent the (quantitative) knowledge human designers have of the functional and morphological definition of elementary spaces and of their relationships.
Reasoner 'B' requires the computer system to have an archive of building plans, prospects and volumes. The computer starts from one of these structures and activates a strategy of deformation of the 'default' object in order to attain a solution which complies with the project's specifications.
This approach implies that building objects could be formally represented with great efficiency and generality. In [3] a formalized representation of the building object has been presented. It uses the notion of matroid and, already at the wire-frame level, allows us to:
i) recognize building components;
ii) calculate the quantity of the comprised elements;
iii) retrieve components' cost and performance data from an internal database and assign them to the said components.

iv) retrieve the necessary data to carry out calculus subroutines (e.g. structural, thermal, acoustic, daylight tests, etc.).

Reasoner 'C' questions reasoner B's default choices; in other words, it searches the inventory of possible choices and selects the item on which reasoner B will further operate. Reasoner C would also have the ability to analyse and implement aesthetic and formal criteria of choice at a later stage of the work. At this, writing, however, reasoner C'S inventories do not allow critical reflection peculiar to Architecture; the reasoner limits its analyses and subsequent choices to performance and cost factors, adopting a multiobjective approach. It does not take decisions following deterministic criteria but interacts with the operator, and, after exploring ideal alternatives, recognizes the structure of requirements that best suits that case. The reasoner then associates potential building objects (BOs) to these cases and transfers them to reasoner B.

1. *Metadesign stages management. The selection of a BO.*

Choosing one or more BOs to which the logic of the system's other reasoners are to be applied implies that reasoner C uses its knowledge base to find structures that a) come closest to a set of goals that client and/or designer regard as useful (Metadesign of the building object); b) come closest to other requirements of a broader cultural nature.

As for point b), one can foresee that in the future our reasoner will contain procedures for image selection meeting the designer's cultural needs by searching its inventories and interacting with the user. For the moment, however, our discussion is limited to the issue_- included in point a).

As we said earlier, our reasoner directs its choices by employing a multiobjective approach. As we know, such analysis poses problems when, within the set of decision variables, different goal functions diverge in shape (Paretian situation).

Several situations of this kind may occur in building design; the most frequent, however, is the one in which building performance and cost are related. The conflict exists because enhancing performance parameter nearly always corresponds to a rise in construction costs.

2. *The evolution of the preference structure.*

Analysing any multiobjective problem requires the formalization of preferences by which different alternatives are judged. Recent research, however, show that the hypothesis of decision makers capable of *a priori* definitions of a valid preference structure is hardly practicable. We think the position contained in [11] is acceptable: preference structures cannot exist before choices; on the contrary, they develop step by step, in a process of progressive learning during the analysis of real alternatives. *A posteriori* preference structures surely make

better sense. They are unstable when only small sets of analysed information are, available, but beyond a certain threshold level, they become reliable and thus capable of generating sensible objective-vectors.
With the specific aim to go beyond such a threshold, the expert system:
i.) searches its 'memory' and analyses the features of the formalized standard realizations;
ii.) generates, in combinatorial explosion, technological alternatives on the basis of such standard realizations. It thus activates an exploration process within the scope of goals and unfolds 'local' preference structures which, analysed together with the cost variable, allow 'marginal' evaluations.
In fact, client and designer may regard certain performance levels (above the minimum level of normative prescriptions) as acceptable. only after full consideration of the price they are prepared to pay in terms of ideal costs or of the other performance levels.

3. *The interaction with Castorp system's other modules.*

As reasoner C is capable of evaluating building objects' technical and economic features, it is able to work both on the items included in its inventory and on the (spatial or technological) modifications proposed by the other reasoners.
During design work, the decision-taking procedure takes place in several passages in the logic of reasoner C, as is shown in figure 1 [2] (the steps are thoroughly described in [8]).
The logic which supports the generation of technological alternatives (step 2.1.2.) follows the spatial deformations, typical of reasoner B. For the moment, it is considered as a set of reasoner C's sub-routines, although it is not impossible for them to become a complete module in the future ('reasoner D'?).

4. *Reasoner C today*.

If the cultural features previously referred to are omitted from our discussion, evaluating a BO is conceptually similar to modifying technological or typological features. For a simpler description of the following example, a residential typology with pre-defined dimensions was assumed in which some of the technological features were free to vary.
The system analyses the typological variants in succession (step 2.1.2 in figure 1, all the possibilities are considered). We are planning to develop the logic of technological alternatives generation in an A.I. environment so that technically insignificant solutions will be prevented from reaching further stages.
The procedure tackles the problem of performance evaluation and alternatives' cost optimization in two stages. The first

stage inspired by the Electre methods [9] [10] and develops accordingly:

1) setting up a database in which the following points are defined for each alternative:

la) a weights vector representing the preference structure (a matrix would be more reliable);

lb) discrepancy levels (to prevent comparisons between alternatives with too diverse a behaviour);

lc) minimal performance levels (normative and/or performance filtering)

ld) matrix of the alternatives' behaviours with respect to the considered requirements.;

2) for each pair of alternatives a_i-a_j, searching for the threshold level a_{ij} of the 'concordance test' to allow 'outranking relations';

3) definition of the matrix of the values of an for all the pairs of alternatives (corresponding to a weighed graph);

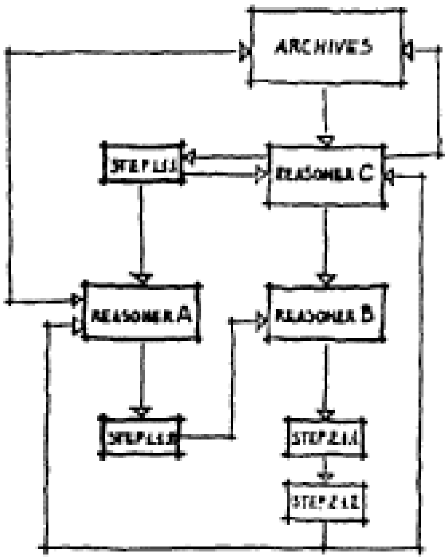
4) for each alternative, calculation of the average outranking' index Pi;

5) ranking of the alternatives according to the Pi index, defining the set of all possible rankings associated to the different preference structures.

After stage 1 a set of solutions are found and ranked according to a strictly qualitative criterion (index P). The problem is now to carry out further on the basis of realization costs. This second stage makes use of a variant of the Worth Trade-off Method (SWTOM) [7] [4]. Using this method, the choice of the various solutions is made by considering marginal shifts of quality and cost indexes.
The solution can easily be found by setting an admissible distance between the absolute maximum of the qualitative index and the (parametric) solution and by minimizing the cost function.

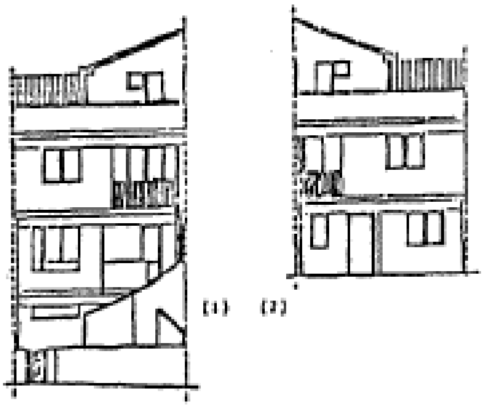
5. Our case study.

We chose a terraced house currently under construction in Ancona as our case study. It is a block of 6 apartment-erected on a slope with an average gradient. Each apartment has 4 stories. Figure 2 shows plans and prospects of an element of the block. For a simpler representation, 7 hypotheses have been isolated among all the possible situations. The variables include the technology adopted for the structural system, opaque and transparent vertical closures, internal partitions and partitions between apartments. Possible upgrading include: covering thermal dissipation points, different finish quality levels and the installation of a small lift connecting the four stories of each apartment.
The alternatives were analysed considering the following requirements:



I.I.I. Environmental metadesign of the system's spatial elements
1.1.2. Functional-spatial design of the system's spatial elements
2.1.1. Functional-spatial design of the building
2.1.2. Technological design of the building

FIG.1



1) Western prospect
2) Eastern prospect
3) Garage storey
4) First storey
5) Second storey
6) Third storey

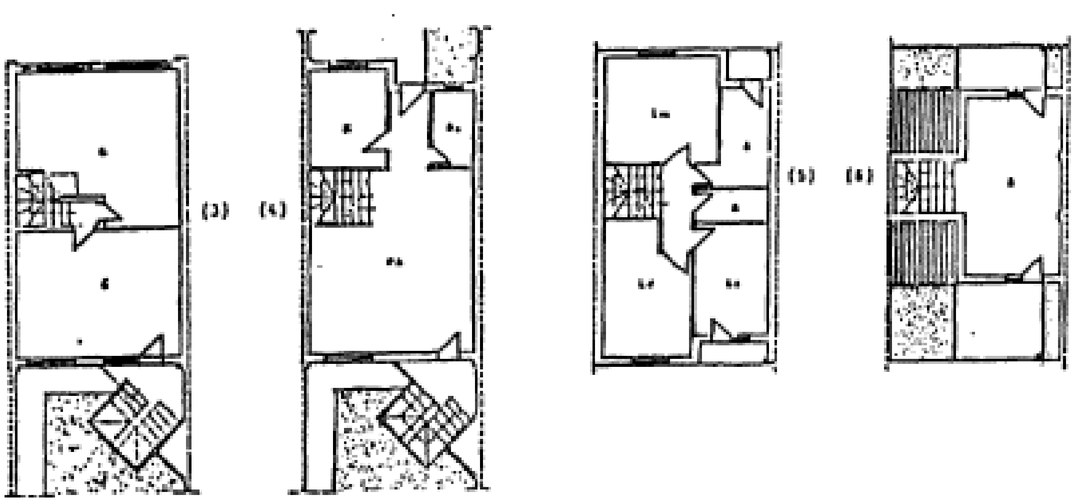


FIG.2

al) durability and maintenance of external surfaces;
a2) usability and internal finish level;
a3) structural efficiency;
a4) acoustic insulation (average wall insulation);
a5) thermal insulation (global dissipation coefficient Cd);
a6) thermal comfort (internal variations);
a7) visual comfort (average daylight factor).

Requirement a3 was compared to normative prescriptions, but for al and a2 we thought it enough to give an assessment.
As we said earlier, if the designer and/or the client cannot give all the information needed to completely know their preference structure, P (with the indicated procedure) cannot produce a quality ranking of alternatives. It can only be a tool to find the alternatives that the decision makers may reach after considering realization costs and budget constraints.
Figure 3 shows the variations of P for each project alternative (numbered from 1 to 7) in relation to changes in the weight of a requirement (W (5) in our case).
The chart informs us of a marked instability of the index P for the alternative's and of the subsequent ranking, corresponding to a variation from the starting situation to a value of W (5) included between 0.4 and 0.5. For W(5) $\geq$ 0.5 the value of Pj stabilizes whenever the difference between the value of W(5) and that of the other requirements is significant. It is therefore arguable that there is a threshold value of Δ W(5), beyond which it makes little sense to further our exploration (in our figure, for ΔW(5) $\geq$ 0.4, being W (1), W (2), W (3), W (4), W (5), W (6), W (7) = 0.1, the values of P become stable).
Having found the threshold ΔW for one requirement or for a combination of requirements, one can draw the corresponding charts of the ranks to be confidently associated to the preferences thus made explicit. These account for "local' situations included in the range of objectives (figure 4).
One's exploration may be continued even further by inserting normative or functional filters (minimum performance values) or by varying more parameters at the same time.
In figure 5 the decision-maker's preference structure is set (expressed by the order along axis P) and the admissible distance from the absolute maximum ε_{1p} is also set. The criterion of cost minimization makes it clear that 3 is the solution to be looked for. Had the distance been ε_{2p}, alternative 4 would have clearly been the solution.
Reasoner C, during both its procedural stages, always considers the fundamental goal of exploring a set of solutions aimed at project criteria, whether they be performance requirements or foreseeable realization costs. Reasoner C's output is readily handled by the other two reasoners and the whole procedure stops when the solution attained lies in the interval p and which are regarded valid during design.

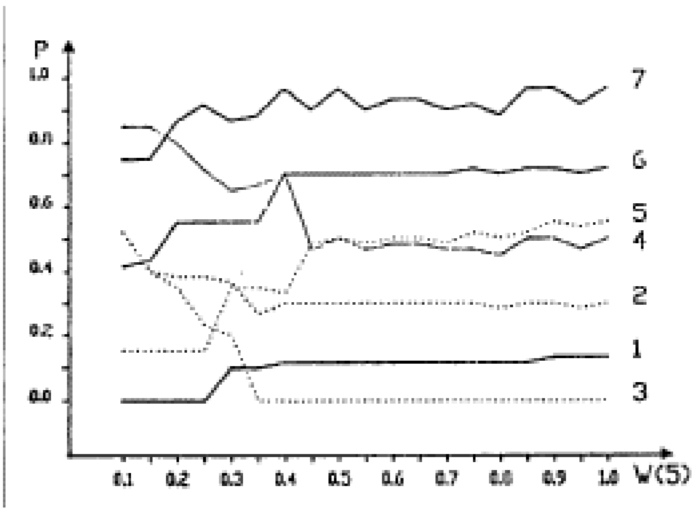


FIG. 3

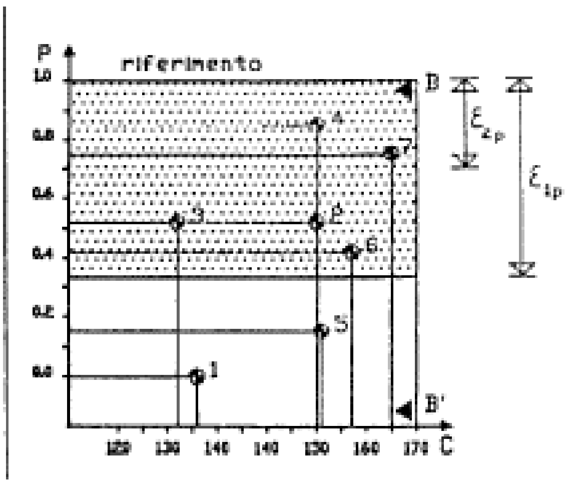


FIG. 5

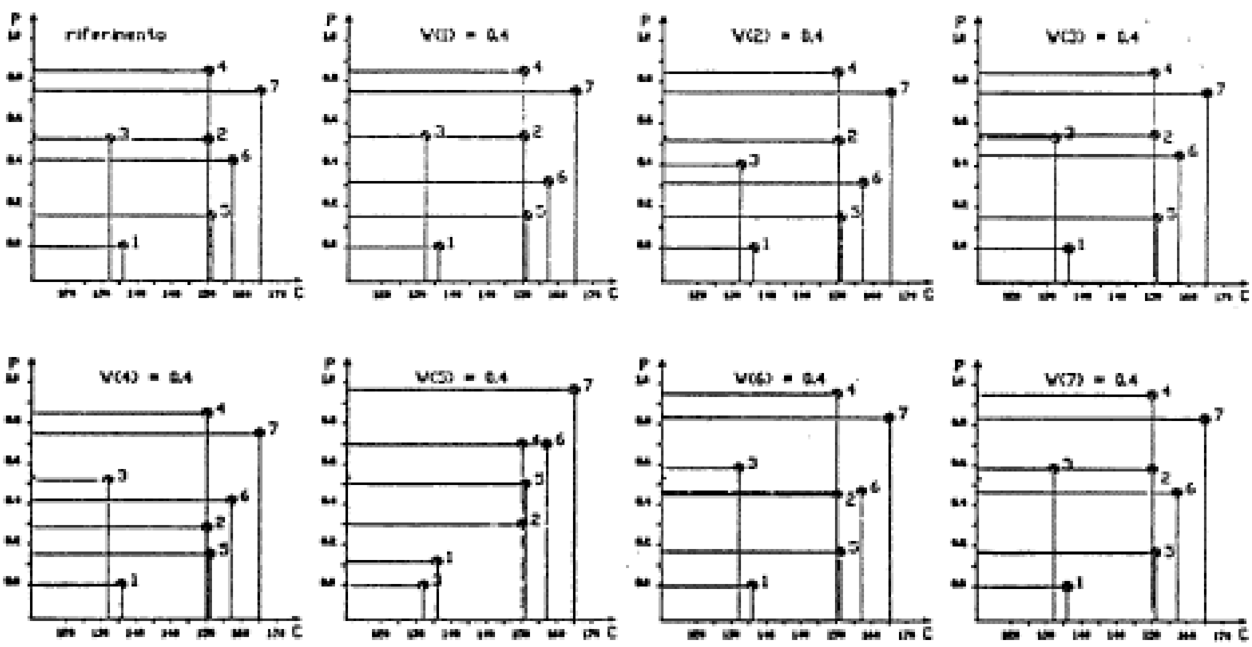


FIG. 4

6. Conclusions.

An example of the application of reasoner C of the Castorp system has been presented. Its capabilities make it suitable for design contexts, however one may also use it in the following:
i) Target definition in building preliminary planning;
ii) Setting design guide features;
iii) Evaluation of tender offers.

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