DECISION SUPPORT SYSTEMS (DGE) IN COMPUTER AIDED ARCHITECTURAL DESIGN (CAAD)

Valerio Calderero, Alessandro Giangrande, Paolo Mirabelli, Elena Mortola

University of Rome
Via Gramsci, 53 00195 Rome (Italy)

1. Introduction

The paper describes a new procedure of design management and the results of its application to architectural design in an exercise developed in a didactic context.
The procedure requires the participation of all "actors" (i.e. designers, experts, clients, users. etc.) involved in the design process and which contribute, directly or indirectly, to obtain the result.
By generating and developing alternative design solutions, this procedure allows the exploration of a region of the performances space which is generally more vast than that explored by the traditional designer.
From the methodological point of view the procedure considers the design as a progressive, cyclic process In which phases of generation (or transformation) of design alternatives con alternate with evaluation
The designers, taking into account the constraints (economical, technical, normative) can proceed to generate design solutions to satisfy the objectives of all the actors.
The solutions are therefore evaluated explicitly by the aid of a decision support system (DSS).
The evaluation has the purpose of guiding the designers in the choice of design actions to Improve the quality in relation to the objectives and, in a more advanced stage of the process, to reduce the number of alternatives, eliminating the solutions less valid.
In this process of converging the non technical actors (i.e clients, users), that are invited to validate the analytical valuations of the design team, take an essential role.
The following work describes In detail the procedure of design management and the results of a partial application to an exercise of architectural design developed by the students of a post-graduate course in CAAD, recently Instituted at the Faculty of Architecture of the University of Rome, under the guidance of some teachers of the course.

2.The procedure of design management

The concepts and methods on which the procedure is based are the results of studies developed in the field of various disciplines, as operational research, organization theory and social decision making.

These studies have put in question the rational model of the mathematical decision theories, substituting the concept of decision as process against that of decision as result.
Moreover it deals with passing from one concept in which the decision maker and the objective are one and the information is complete to a new conception, that allows the consideration bath of plurality of the actors and objectives, and of imperfect information.
In these studies are important ideas as value system, information system, relation system, actor and action (Cyert and March 1963, Jacquet-Lagreze et al. 1978, March and Siman 1958, Moscarola 1980, Ostanella 1983, Simon 1957, Sfez 1973).
The design process is considered by the procedure a decision-making process with strong technical characteristics in which, besides designers, are involved other categories of actors who can influence its evolution and condition its result.
This process can moreover be analyzed and, within certain limits, managed with the aid of methods based on concepts shown above. The procedure requires, in the first place, the analysis of the decisional context, with particular reference to the identification of the actors their roles, their needs and/or objectives. The following phases of the procedure are:

1) definition of design objectives and their weights
2) identification of constraints
3) generation of alternative design solutions, satisfying the objectives and respecting the constraints
4) construction of all criteria which can "measure" the performances of alternatives in comparison with the single objectives
5) global comparison of alternatives with the aid of a decision support system (multicriteria analysis)
6) identification of "critical" objectives and research of design actions aimed at solutions improvement
7) validation of the evaluation results made by the nun technical decision makers
8) selection of the project which must he developed in executive form and realized.

If the decision makers disagree with the designers upon the projects evaluation or suppose that no project is good enough to be chosen, the design team must rerun the procedure (all or in part), considering with particular attention those steps that have caused the discrepancy of opinion.

2.1 The decisional context of design process

The design team identifies the actors and their roles, their needs and/or objectives related to design problem.
This aim is anything but easy to attain.
Let us consider, for instance, new housing construction the program of which calls for adjustment of requirements to the needs of the specific users.

The insufficient habit of the future residents to explore their own needs in a systematic way can compromise the identification of their requirements.
Once articulated the design problem in decision areas related to the potential needs (for instance, the relations between various functional areas of the dwelling, the flexibility of use of the space, etc.) the designers con obtain information utilizing the traditional survey tools, an questionnaire and interview.
To obtain exhaustive and reliable answers the designers must submit to the users drafts or photos of realized projects.
This repertory can be utilized to show the various decision areas to the users and help them to communicate their needs and preferences referring to concrete examples.
The identification of actors objectives is also problematic.
Some objectives, in particular, can be implicit during all the design process.
For instance, it is not conceivable that a constructor can make known an objective as "maximum profit by poor or shoddy material".
Needs and objectives, after all, are not necessarily constant, but can evolve during the process.
For instance, the value system of a particular actor con be influenced by the information which becomes available during the process.
Consequently, the actor can be induced to modify some objectives and to state new objectives during the next phase of the design process.
The above puts in evidence how complex the purpose is to analyze the decisional context of a design problem c but it does not invalidate the procedure of design management.
The evolutive nature of the procedure in fact allows the utilization of a set of design objectives which can be not necessarily exhaustive and perfectly structured, so long as the quantity and the reliability of objectives are sufficient to generate design solutions.
Effectively, the procedure does not ask that the objectives are defined once and for all: in effect the identification and use of design objectives, which represent better the needs and objectives of the actors, is ever possible in the next phases of the process.

2.2 Identification of design objectives and weights

The chief of designers defines a set of design objectives, which reflects the needs and objectives of various actors (designers included).
Aided by nit expert of program planning methods, the thief proceedes to organize this set by means of the "relation of subordination" [1].
The application of this relation allows the organization of objectives according to a hierarchic structure, the so called "subordination hierarchy" (Sage 1977).

[1] The objective A is subordinated to the objective B if the satisfaction of A represents a means to satisfy (or contributes to satisfy) B.

At the hightest level of the hierarchy are collocated the objectives axiological or strategic, which reflect primary needs or intrinsic values of the actors.
Going progressively down to the lower levels, the objectives are over more specific and instrumental, and then more utilizable for the identification of design actions.
Thanks to the transitivity of the relation of subordination it is sufficient that a design solution satisfies all the objectives of the lower levels and satisfies indirectly all the others.
That is true if all aspects of every objective are "covered" completely by the objectives wore specific directly subordinated.
The use of interactive computer methods (Fitz 1975, 1976) can help the construction of the hierarchy.
In general it is better to use some empiric techniques, that allow the generation of objectives, to assure the completeness or to provide for lack of specific objectives.
Among these, one of the beet techniques is that of "how and why" (Sale 1977).
To generate the objectives subordinated to a considered objective, going from the upward direction to the downward direction of the hierarchy, it is sufficient to enunciate the same objective and ask: "how?".
Going from the downward direction to the upward direction to identify a strategic objective utilizing objectives more specific the suitable question is: "why?".
Once constructed the subordination hierarchy the chief must assign the weights to the design objectives.
To define these weights, the chief must assume the responsibility of assigning diverse importance to the objectives of the various actors considering their roles and the relations existing between the design team and the other actors.
From the technical paint of view the weights attribution is facilitated by the subordination hierarchy.
If the hierarchy satisfies the property of completeness, it is possible to proceed to the assignment of the weights for every subset of objectives subordinated to a given objective and belonging to the same level of hierarchy (Sage 1977).
Once attributed to the objectives of each subset "temporary" normalized weights (that is their sum should be one) it is possible to obtain for every objective of hierarchy the "effective" weight multiplying its temporary weight for all these of the superior levels to which it Is directly or Indirectly subordinated.
This method allows the achievement of the weights of the objectives comparing the importance of the same objectives only within each subset, without proceeding to the direct comparison of each objective with all the others.
When the number of objectives is high, such a comparison can be impossible or produce results of little worth.
Thanks to the procedure utilized, the weights of the objectives belonging to all the lower levels are normalized.
The attribution of the temporary weights to the objectives of each subset can be made in many ways.
One of those is represented by the technique of "rating" (Lichfield

et al 1975, Voogd 1983) the person who has the duty of assigning the weights has at his disposal a budget of 100 points to distribute among the objectives in the way that the number of the points assigned to each objective reflects its importance.
To obtain a set of weights normalized it is enough to divide by 100 the points assigned to each objective of the subset.
Another method is based an the technique of paired comparisons (Saaty and Alexander 1981). With this technique it is possible to go directly to a set of normalized weights according to the judgement of relative importance expressed on the base of a scale of integers (1 to 9) to measure the "intensity" of this importance.
Finally it seems opportune to mention a method recently elaborated by Vansnick (1985) that appears competent to give results more reliable and satisfactory in the noncompensatory decision-aidmethods.
Once constructed the subordination hierarchy and assigned the weights to the objectives, the chief submit the same hierarchy and the set of weights to the principal actors. On the base of the observations made by the consulted actors, the chief can decide to modify the hierarchy and/or the weights.
The set of weights can be visualized by a diagram which shows in abscissa the objectives pertaining to the lower levels of the hierarchy and in ordinate the weights. Such a diagram, that facilitates the comparison between the objectives in terms of importance, is called a decisional profile.

2.3 Identification of constraints

Not less important then the construction of the subordination hierarchy of objectives is the identification of the constraints which can condition strongly the development of the design process.
The constraints can be of different nature: economic, technical, normative, etc. An upper limit of the costs of designing and building rigidly imposed by the customer represents a typical example of economic constraint.
An example of technical constraint is constituted by the impossibility of realizing a particular structural solution for reason of the limitations of the actual constructive techniques.
The hydrogeological and environmental constraints, which forbid the construction of buildings and infrastructures in specific zones, represent usual examples of normative constraints.
The distinction between objectives and constraints is important.
While the latter must be most rigidly respected by the designers, the objectives can be satisfied at different levels.
A design solution which does not respect any single constraint must be declared "not feasible".

2.4 Generation of alternative design solutions

This step in the procedure involves the division of a design team into subgroups or units (eventually constituted by a single designer) coordinated by the chief of the project.

Every unit must proceed to arrive at a sketch design solution, that satisfies the objectives in absolute respect of the constraints.
By the considerations referred to the section 2.2, the designers can make exclusive reference to the specific objectives, that are placed at the lower levels of the subordination hierarchy.
The inevitable presence of conflicting objectives forces the designers to operate frequent tradeoffs: the design choices must take into account, within the limits of possibility, the weights assigned to the objectives.
The units can proceede in two different ways:

1) to generate "free" solutions
2) to make "a priori" a choice in order to limit the spate of the design solutions (e.g. a typological choice), identifying a design variable able to influence strongly the result and generate a set of solutions corresponding to different values of the variable.

If the first method of procedure allows the exploration of a more vast region of the solutions space the second permits an analysis more systematic. The choice of how to proceed must be decided according to the nature of the problem and of its context.
From the operative paint of view the procedure does not exclude the possibility of utilizing methods which help to identify the structure of the design problem. For instance, once the objectives are agreed with the design requirements and identified the links of concurrence or contrast among the same objectives, it is possible to generate design solutions with the help of a "diagram", that allows the structuring of the design problem in independent sub-problems (Alexander 1964).
In this step of the procedure it can be of great utility a knowledge based system, that allows the discovery lnteractively of the eventual violation of constraints and controls with continuity the performance of the solution with regard to the single objective.
In conclusion it seems appropriate to point out that the "waste" of design energy, necessitated by the generation of more alternatives, is more apparent than real.
Converging a group constituted by at least 4 or 5 designers an a single project can, in fact, prove negative: in this phase of the design process, that implies creative choice and of individual character the team work can be counterproductive and the choice of "compromise" solutions have a negative result (Jones 1970).

2.5 Construction of a set of evaluation criteria

To evaluate alternative designs, generated in this preceeding step of the procedure, it is necessary to wake an evaluation criterion correspond to every objective pertaining to the lower levels of the subordination hierarchy .
A criterion can be qualitative or quantitative.
To define a qualitative criterion it is sufficient to define a discrete and ordered act of levels such as - bed. unsatisfactory, satisfactory, good, best -.

This set, once associated with an objective and the possibility of assigning every alternative to a specific level has been checked, a preference structure which permits a comparison among alternatives in respect of the considered objective becomes univocally determined.
A quantitative criterion is defined by a continuous or discrete set of values that can assume an indicator which varies with the performance of the alternative with regard to the given objective.
To establish a preference structure coherent with the objective, it is necessary to define how the performance varies according to the indicatory namely to construct the value function that is made to correspond to each value of the indicator a measure of performance.
The choice of type of criterion to adapt (qualitative or quantitative) depends on the nature of the corresponding objective and/or on the difficulty that the construction of the value function implies.
Once all the criteria are constructed, the chief-designer examines the alternative designs generated in the ambit of each unit and proceeds to evaluate each single project.
In this task the chief-designer can be aided by experts who are able to supply precise elements of judgement, on the basis of their specific competence.
The set of values that the alternatives assume on the criteria defines the evaluation matrix, of which the lines and columns represent the alternatives and the criteria respectively.
To facilitate the analysis and the comparison of the performances of the design solutions it is convenient to represent the evaluation matrix through a single diagram in which the criteria are represented in abscissa and the performances in ordinate.
Joining the points that correspond to the performances of the some alternative, as many curves as alternatives are obtained (evaluation profiles).
To facilitate the reading of this diagram it is appropriate to coincide on the axis of the ordinate the extremes of the intervals within which vary the performances on the criteria, adopting, if necessary, different scales for the different criteria.
It is noted that the visual analysis of the evaluation profiles does not allow the identification of the best design solution (taking for granted the non-existence of a dominant solution) nor even less the construction of a rank of the solutions in decreasing order of preference.

2.6 Overall comparison of the design alternatives

At this stage the alternatives come to be compared with respect to all the criteria with the help of a DSS.
In this specific case we used an interactive DSS, sufficiently userfriendly to be used by a designer, based on ELECTRE II (Roy et Bertier 1973).
This DES is currently running on Olivetti M20 personal computer and is in course of preparation a version for IBM PC and compatibles.

ELECTRE II requires as input the evaluation matrix the decisional profile, the concordance thresholds and the discordance sets, which have to be defined by the chief-designer.
The preorders obtained by means of this DSS can depend both on the concordance thresholds and an the discordance sets: a sensitivity analysis, effected by changing the thresholds and sets allows the testing the stability of the obtained preorders.
Through the classification obtained it is possible to discriminate between the best design alternatives (belonging to the higher classes of the preorders) from these of the worst.
The exclusion of the latter from the design process can be premature at this point, not being possible to establish whether such alternatives would be susceptible to substantial improvement that could better their comprehensive performance, rendering them comparable or superior to those judged at the moment more valid.

2.7 Identification of the "critical" objectives and research of design actions directed to improve the solutions

The crossed analysis of the evaluation profiles and of the decision profile allows the chief-designer to identify the "critical" objectives, i.e. the objectives that, by reason of their greater weight and of the lower level of performance obtained by the design solution, can contribute in a determinant way to lower the comprehensive value of the some solution.
Once the critical objectives of every alternative have been identified, the designer-chief urges the design unit to elaborate in a short time direct actions to improve the projects, with reference to such objectives. These actions can be worked out in a schematic manner, on condition that it allows the design chief to evaluate the results in terms of performance on each single criterion with the aid of the DSS.
Before validating the modifications introduced, the designer-chief proceeds to compare the modified solutions (i.e. the evaluation profiles) with all the others, modified or not.
It is noted that the evaluation profiles of the solutions modified can differ from those of the corresponding solutions not modified, not only by the performances that have been improved as a direct consequences of the design actions, but also by those that are made worse by the presence of the conflicting objectives, by reason of which it is possible that the improvement of a performance becomes difficult or even impossible without the worsening of another.
The procedure at this point goes back to point 2.6 to carry out the analysis of all the evaluation profiles of the solutions, modified or not, by means of the DSS.
Such analysis defines a new classification in which each modified solution can precede the corresponding solution not modified.
In this case the designers can proceed to modify definitely the projects which have been elaborated on the basis of the proposed actions.

2.8 Validation of evaluation results

The design alternatives obtained are submitted to the judgement of the non technical decision makers.
Such judgement has to be expressed directly an the basis of the worked out projects and compare with the evaluation of the design team (evaluation profiles classification).
When the evaluations of the majority of the decision makers does not agree with those of the designers it is necessary that the design team develops an analysis to specify the insufficiencies or errors in the process of modelling of the actors' preferences
A deeper analysis of the decisional context, to give an example, could show the need to modify the design objectives and/or their weights because they do not correspond to the real needs and to the objectives of the actors.
It is observed that this weak correspondence, difficult to determine at the beginning of the process, can be better shown In this phase In which the actors can compare their own needs and their own objectives with concrete design alternatives.
The passage to the next point in the procedure can be realized only when there exists a substantial agreement between the evaluation of the designers and the judgement of the decision makers.
In the case of strong disagreement between them, it will be the duty of the design team to define the motives and proceed, if possible, to find a "compromise" alternative.

2.9 Choice of the project to develop In executive form and realization

The non technical decision makers, also in agreement with the designers about the order of preference of the design alternatives, could decide that no solutions, including that which occupies the first position in the classification corresponds fully to their expectations.
In this case it is necessary that the design team proceeds to the new elaboration or remaking of the projects to improve the performances and arrive at a design solution, that can be, at least, accepted by the majority of the decision makers and therefore realized.

3. Application of the procedure to an exercise of architectural design

The exercise has been developed within the post-graduate course in CAAD.
On the basis of the proposed theme (a residential project localized in the Pontina Lowlands), the exercise assumed a priori some constraints regarding the form and dimension of the lot (110 x 110 m.), the housing typology (courtyard terrace houses an two floors), the number and the area of the apartments (40 homes of about 110 sq m. each).

The decisional context, simulated by teachers and students of the course has been voluntarily simplified limiting the categories of actors to three: the customers-users, the designers and the expert of decision-making processes. The simulation of customer-users has been effected by all the students of the course and by their families.
In the simulation, the design-chief and the expert of decision-making processes have proceeded to identify the needs and the objectives of the customers, using specific record cards and questionnaires.
The analysis of information gathered has allowed the identification of three diverse dimensional typologies of family units and the construction of a list of design objectives related to specific requirements of the customers.
To these objectives have been joined others belonging to the design team, finalized principally to safeguard the architectural quality.
Utilizing the method described in 2.2, the designer-chief and the expert of decision-making processes have proceeded to the construction of the subordination hierarchy of the objectives (fig.1).
On the basis of the information gathered, the design-chief has therefore assigned the weights to the objectives of the hierarchy, after having attributed "temporary" weights to every subset of subordinated objectives by means of the technique of rating.
With the purpose of proceeding to the generation of alternative design solutions, the design team is divided into 5 units, each one made up of one or two students [2].
It is decided also to constrain each design unit to develop a project characterized by a different interaxis of the dwelling, namely 4.5 m., 5 m., 6 m., 7 m. and 8 m..
This design variable has relevant consequences both to the scale of the residential area (dimension of the courtyard, distribution of the communal spaces, etc.) and to the scale of the dwelling (division of the interior, environmental requirements, etc.).
To generate the alternatives, MacDraw and SCRIBE, two CAAD low-cast programs running respectively on Apple Macintosh and Apple 2e personal computers have been put at the disposal of the designers.
By way of example fig.2a and fig.2a show respectively the plans and the layout of the dwelling relative to the projects developed by the design units.
The evaluation of the projects has been carried out by the design-chief using 32 criteria, which correspond to the objectives belonging to the lower levels of the hierarchy.
The evaluation of the physical-technical performances involved the construction of 3 indicators and their corresponding value functions.
The quantitative scores have been referred to a scale of 5 performance levels, corresponding to those used for the other (qualitative) criteria.

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[2] Design unit 1 : arch. Fabrizio Gatti
Design unit 2 : arch. Graziana Capitini and Giuseppe Dominici
Design unit 3 : arch. Fortunato Cupi and Palmira Leone
Design unit 4 : arch. Sergio Bartolozzi and Massimo Guidarelli
Design unit 5 : arch. Paolo Salvi

To calculate these indicators three models have been utilized and particularly:
- the daylight model
- the thermal loss model
- the passive solar beating model

In the first model the daylight factor (DLF) is computed for different points of every room taking into account the geometric and physical characteristics (the geometry of rooms, of transparent surfaces and of possible obstructions).
The DLF is computed adding up the sky component, the externally reflected component and the internal reflection component.
A simplified model (Moon and Spencer 1942) has been used In order to determine the overcast-sky luminance, referred to normalized condition, and the relation of Higbie (1934) has been used in order to determine the sky component.
The natural light has been obtained from the DLF utilizing external illumination, guaranteed for the 90% of the work period, which correspond, for the latitude of the project, to 5000 lux.
The representative value for every room has been obtained doing the average of calculated values on the points of a geometric network on the work plane at the height of 90 cm.
The value function used to evaluate the projects has been obtained by the weighted average of the functions constructed for every room in accordance with the illumination requested by the activities, taking place there.
The second model calculates for every building the thermal loss in terms of a steady state of the temperature, verifies that the loss for volume unit results lower than that imposed by the 1.373176 (for the control of energy saving), taking into account the climatic zone defined by means of degree-day and form factors (surface/volume), determines the cost of the combustible relative to thermal need in the heating period.
The value of the indicator is obtained by the value function, defined by the users in accordance with their financial possibilities.
The third model, using a simplified method In a passive solar system, calculates the solar beating factor (SHFJ for every month in the case that the thermal storage of every room is included between 148 and 220 kcal/c for mq of glass.
For SHF it is understood the percent of thermal need really satisfied by the passive solar system.
The model for the monthly calculation of the SHF utilizes the relations of J. Douglas Balcomb of the Los Alamos Scientific laboratory (1979), which express the SHF in function of the relation between solar radiation and thermal need.
The thermal contribution for the total period of heating and the annual cost of the combustible for heating and the saving obtained from the contribution of the passive solar system are calculated after.
As in the preceding model the value of the indicator is calculated on the basis of a value function, defined by the users, in accordance with their financial possibilities.
Fig.4a relates to the decisional profile and to the evaluation

profiles of the 5 design solutions.
All the criteria are qualitative and made to refer to the same scale of values : bad-1, unsatisfactory-2, satisfactory-3, good-4, best-5.
The global comparison of the alternatives elaborated by the DSS led to the following complete preorder

CLASS	PROJECT (Design unit)
2	4
3	5
4	3
5	2

This preorder is stable when the concordance thresholds are changed within a wide range of values.
The preorder obtained still does not allow the formulation of a final judgement of the projects until critical objectives and design actions to improve the performance are determined.
In the next step of the process the projects of the design units 1,2,4 and 5 have been revised.
The analysis of the decisional profile together with the evaluation profiles has Induced the identification of critical objectives for every solution, in accordance with the methodology described in 2.7.
The new alternatives are shown in the fig. 2b (plans) and fig. 3b (layout od dwellings).
The comparison of all the alternatives (5+4) led to the following preorder (only the 6 first classes are reported):

CLASS	PROJECT (Design Unit)
1	1*
2	4*
3	1
4	2*
5	4
6	5*

(the asterisks point out the solution generated in the second phase of the process)
The fig. 4b shows the evaluation profiles of these 6 projects.
The analysis of the preorder emphasizes that all the revised projects have improved their position in the preorder.
In addition, the projects of the design units 1 and 4, the first and second respectively In the previous preorder, have the same rank in the second step.
All that confirms the Intrinsic capacities of these projects.
The project of the design unit 2 Improved very much, while the original project of the design unit 1 is in the third position.

All that could Induce us to consider the solution with interaxis 4.5 the best, a solution that, at the beginning, looked like the most difficult and problematic.
In addition to these general remarks there assumed some interest the interactive process related to the improvement of the physical-technical performances in observance of the formal design aspects (for instance, the control of window dimensions).
This interactive process of the Improvement of some critical criteria and the control of their consequences on other criteria could be a good direction of research to develop in a possible third step.

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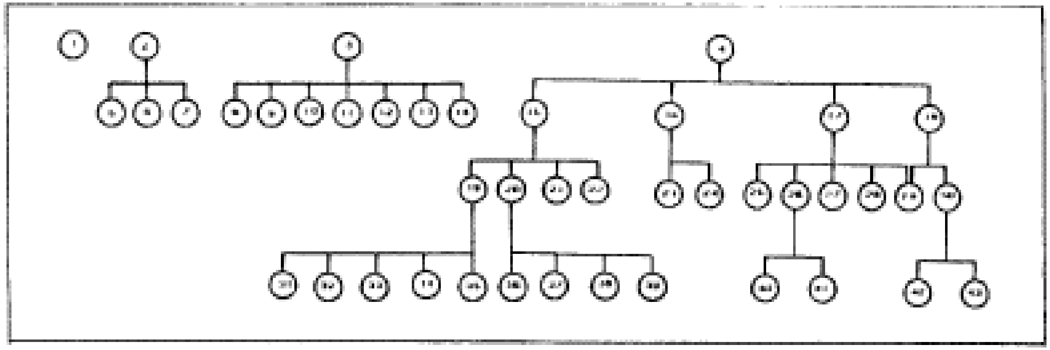
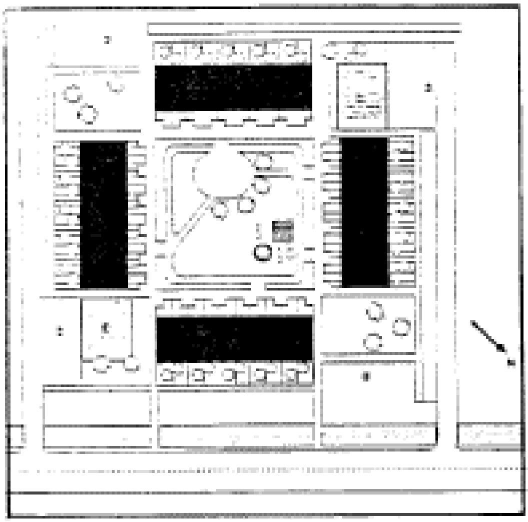


1 - To maximize the formal quality of the architecture
2 - To rationalize the circulation and parking
3 - To receive pleasure from using the communal spaces
4 - To maximize the housing quality of the dwelling
5 - To realize an efficient system of pedestrian routes
6 - To minimize the distance between car-parking and dwelling
7 - To provide a lot for guest car-parking
8 - To render pleasant the passage or the standing in the communal spaces
9 - To avoid interferences between carriage flow and communal spaces
10- To provide the communal spaces with play apparatus and provision for leisure
11- To guarantee conditions of safety within the spaces destined to a play area for children
12- To allow the flexibility of the use of communal spaces
13- To avoid inopportune interferences between activities carried on by different categories of users
14- To keep low the noise in the courtyard
15- To maximize the functional requirements of the dwelling
16- To provide for the security of the inhabitants
17- To maximize the psyco-physical comfort of the inhabitants
18- To minimize the management costs charged to the inhabitants
19- To optimize the layout of the dwelling
20- To guarantee the functioning of the spaces and the distribution areas
21- To maximize the functional integration between the interior of the dwelling and the pertinent external area
22- To allow the functional and dimensional flexibility of the space
23- To facilitate the control of the access space of the dwelling
24- To provide the dwelling with a protected car port
25- To eliminate environmental disturbances connected with the activities within the dwelling
26- To safeguard the privacy of the inhabitants
27- To maximize the visibility of the exterior space from the interior of the dwelling
28- To guarantee natural lighting and direct ventilation to the services
29- To guarantee a good natural lighting in the dwelling
30- To minimize the conditioning costs
31- To respect the needs of adjacency and of the proximity of the functional spaces in the dwelling
32- To reduce to the minimum wasted space
33- To limit the sleeping area in favour of the living area
34- To guarantee a balanced relation in the greatest spatial continuity between the functional areas of the living zone
35- To provide the dwelling with a study of adequate dimensions
36- To guarantee the functioning of the spaces where the communal activity takes place
37- To guarantee the functioning of the spaces where the individual activity takes place
38- To guarantee the functioning of the services
39- To guarantee the functioning of the spaces of circulation
40- To protect the private space from being overlooked
41- To safeguard the privacy of the interior of the dwelling
42- To minimize the thermic loss in the winter
43- To maximize the bioclimatic requirements of the dwelling

FIGURE 1 - THE SUBORDINATION HIERARCHY OF OBJECTIVES



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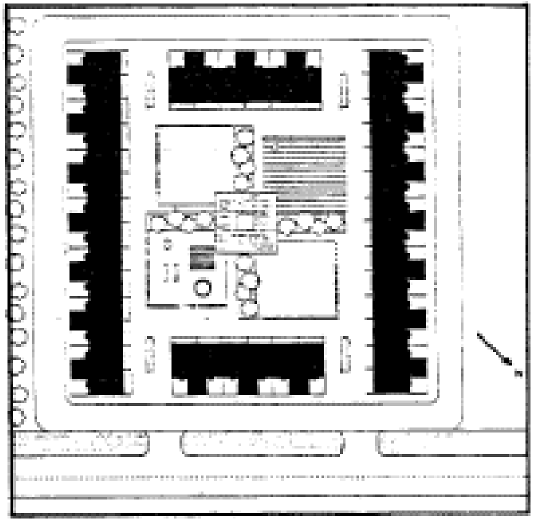

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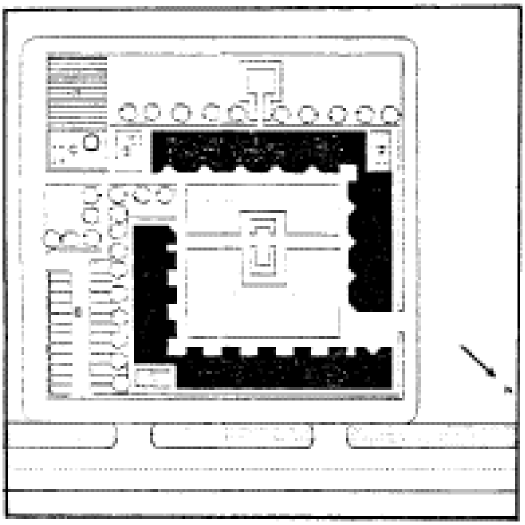

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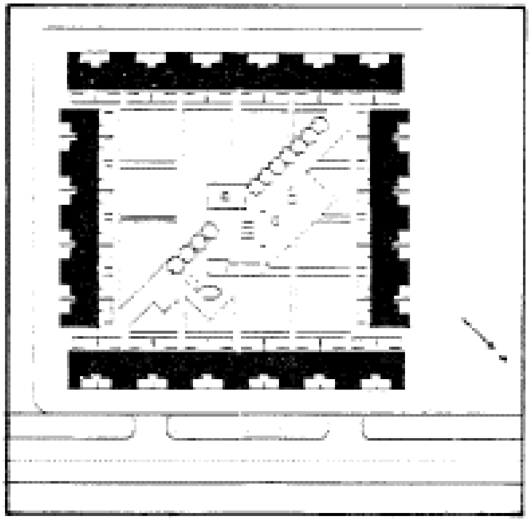

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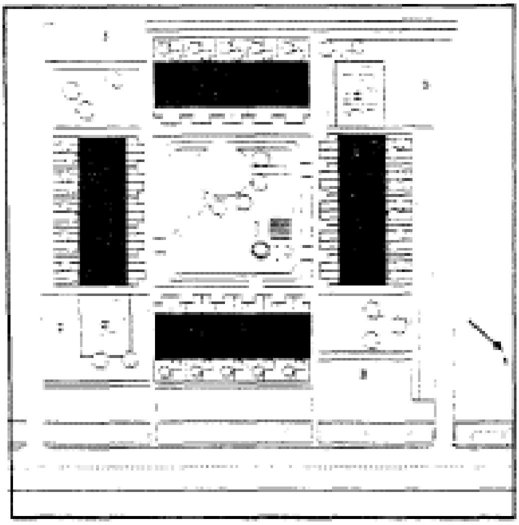
FIGURE 2a - PLANS (FIRST PHASE)



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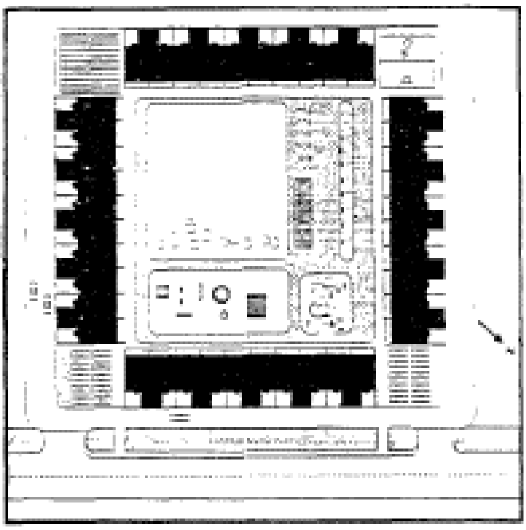

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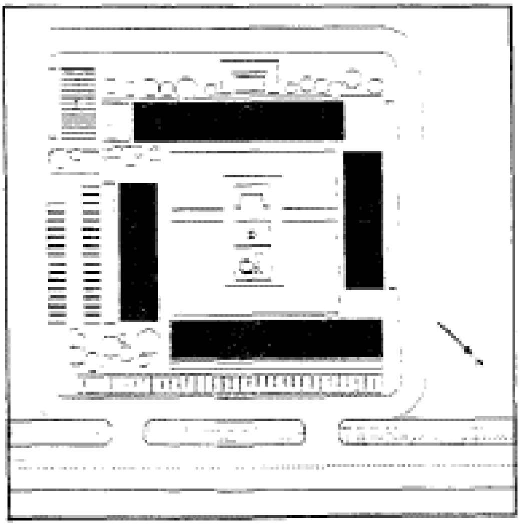

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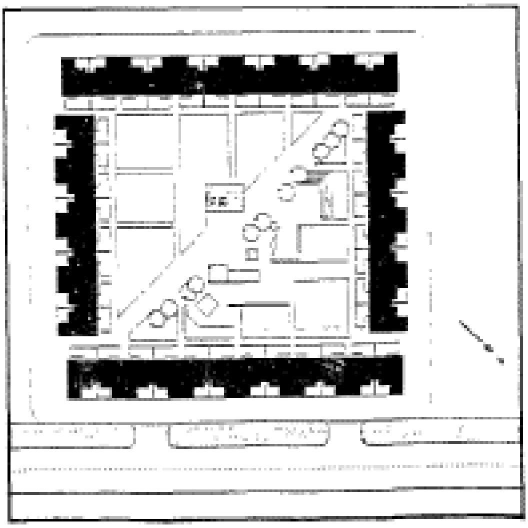

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FIGURE 2b - PLANS (SECOND PHASE)

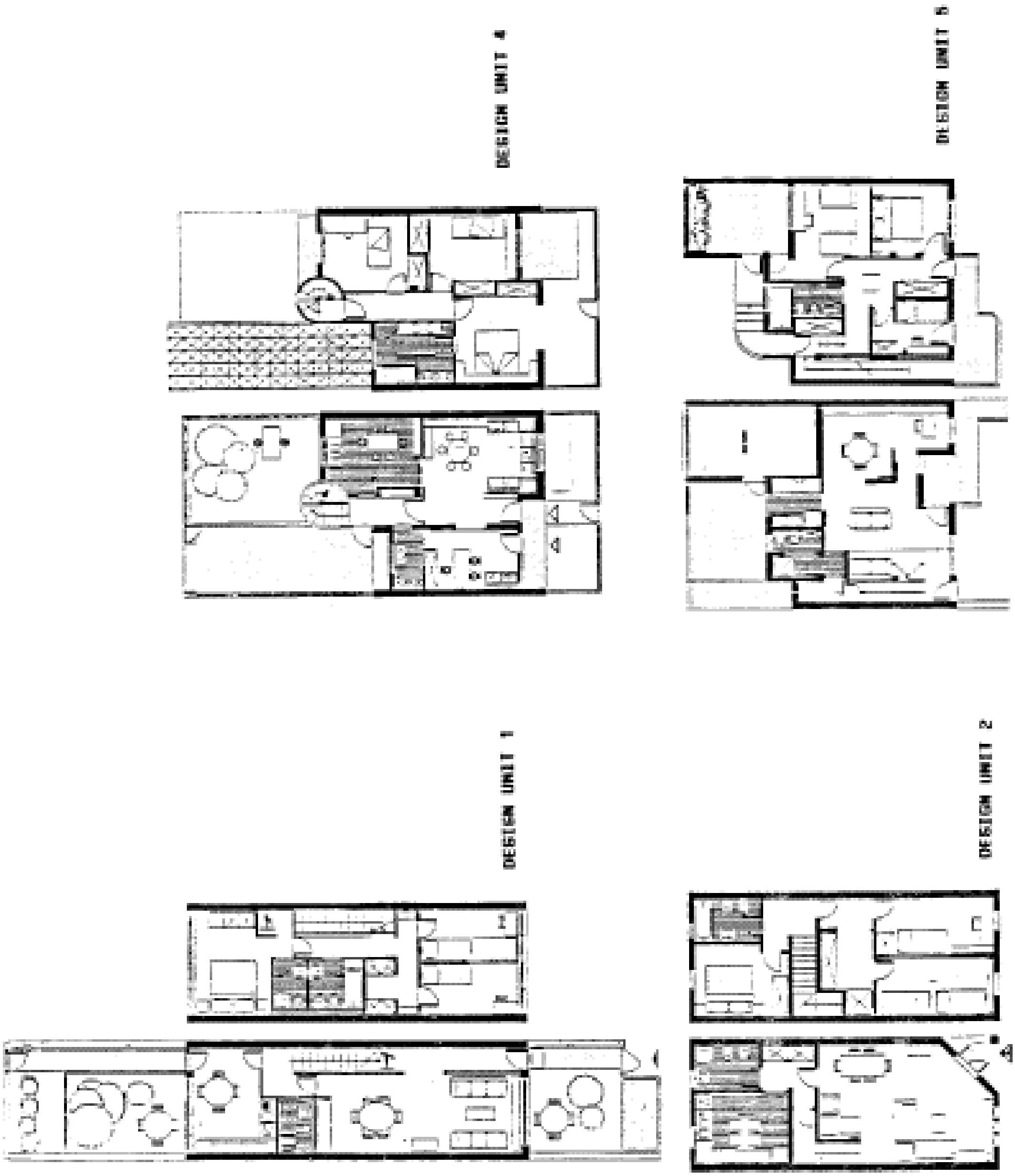

FIGURE 3a - LAYOUT OF DWELLINGS (FIRST PHASE)

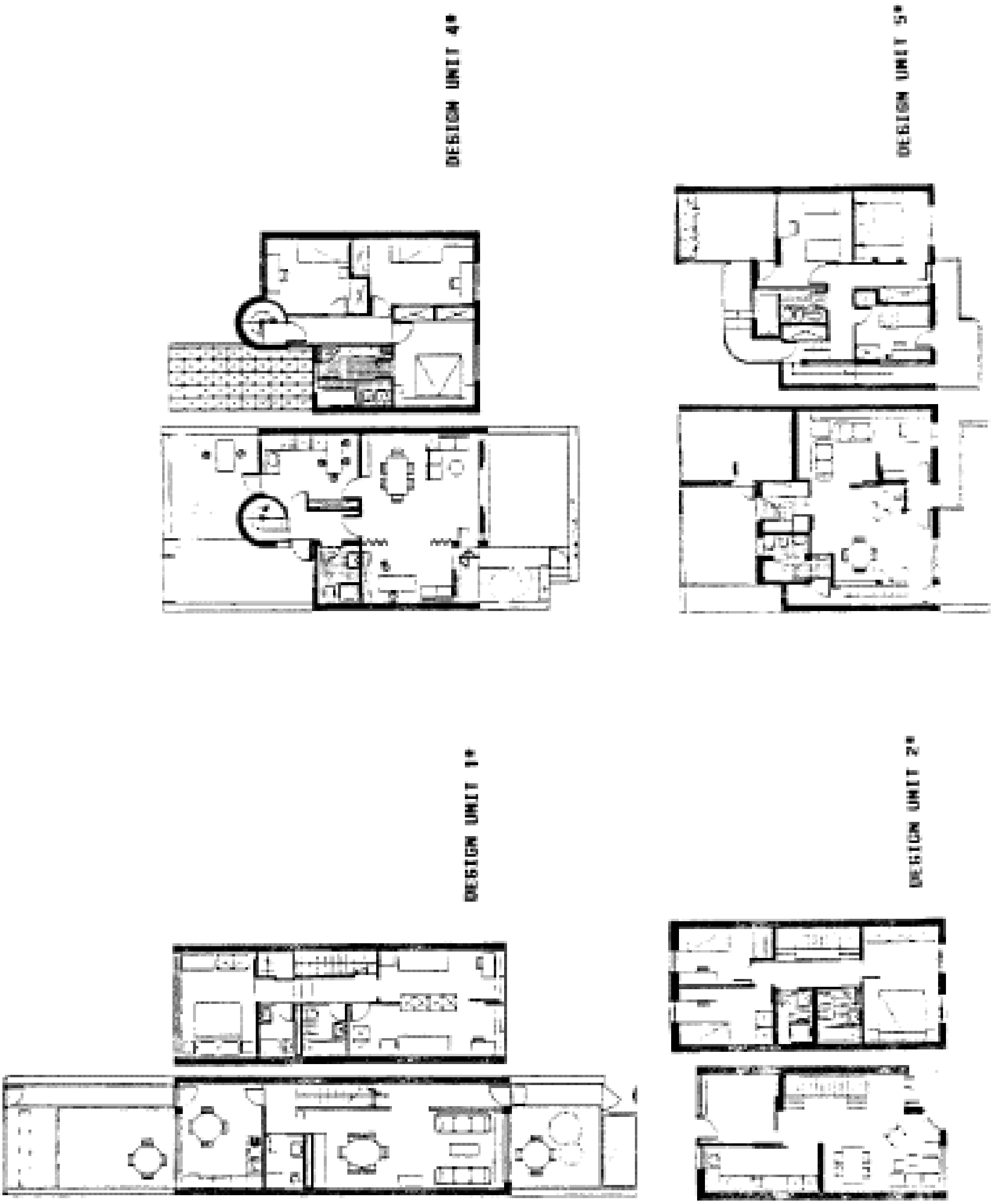

FIGURE 3b - LAYOUT OF DWELLINGS (SECOND PHASE)

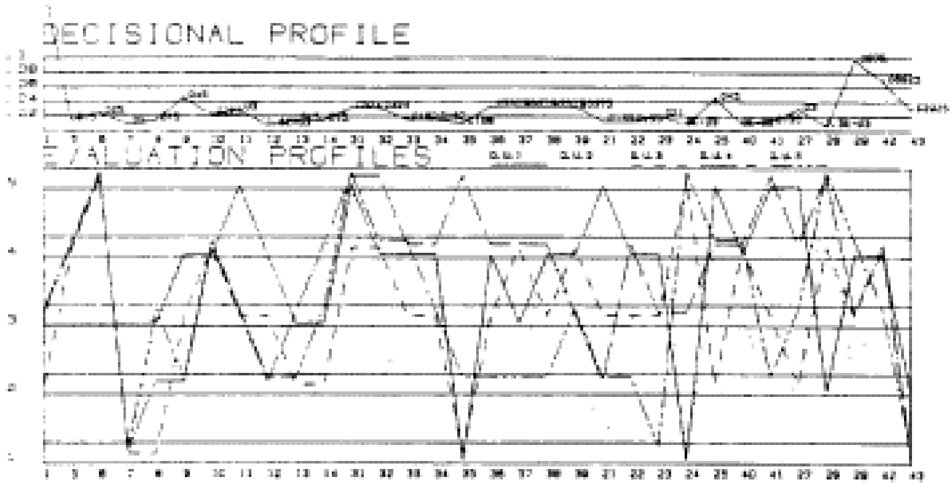

FIGURE 4a - CRITERIA WEIGHTS AND PROJECTS APPRAISAL (FIRST PHASE)

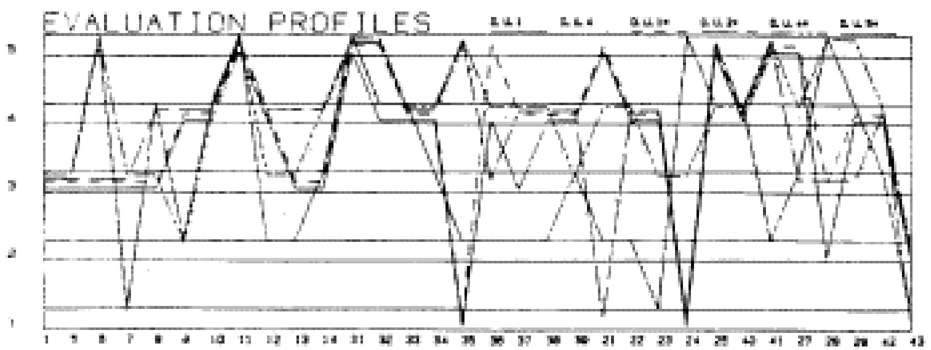

FIGURE 4b - PROJECTS APPRAISAL (SECOND PHASE)

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