
Multicriteria Interactive Tool to Sketch the Building Envelope During First Stages of Architectural Design

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ABSTRACT

This study explores a multiple criteria decision aid (MCDA) procedure to optimize the building envelope during the initial design, where a significant number of choices are fixed and have a determining impact on the future building cost and use.

The objective of the design method is with respect to building costs, for the building construction and use, and energy performance improvement.

An interactive tool has been developed within a multicriteria and multiactors context. In order to improve the architectural response to the client's and regulation requirements, it gives decision-making aids to

- *the project authors, in making up the project architectural forces, in accordance with the actors' objectives;*
- *the client, in reaching objectives of costs, building duration, comfort, and functionality, while assuming responsibilities related to building energy and environmental performances.*

The design tool is organized in two linked modules, to which any actor may go at any time:

- *the first one manages parameters describing the project requirements;*
- *the graphic module allows one to draw a sketch and calculates geometric parameter values that it puts back in the first module.*

Permanently informed on cost and energy performances, the user can search at any time for an optimal scenario giving the best satisfaction or compromise. There are many graphs illustrating the performance sensitivity to parameter variation, as well as an optimization procedure using a genetic algorithm to find the most efficient parameter set.

The software is organized to manage new building projects for houses, schools, and offices (small to medium-size projects).

INTRODUCTION

The approach presented in this paper is an attempt to cope with the difficult problem of ameliorating the dialog between the several actors intervening in the design of a building envelope using multiple criteria decision aid (MCDA) methodologies. The main purpose is to present the MCDA framework

that can help the *sketch design*, the earliest step, as well as a crucial one, in the whole building envelope design.

We can consider three stages that lead actors to the sketch design (see Figure 1). The first is a definition and *negotiation stage* between several private and public actors, where they express their requirements and preferences based on several criteria, parameters, regulations, and constraints. In the

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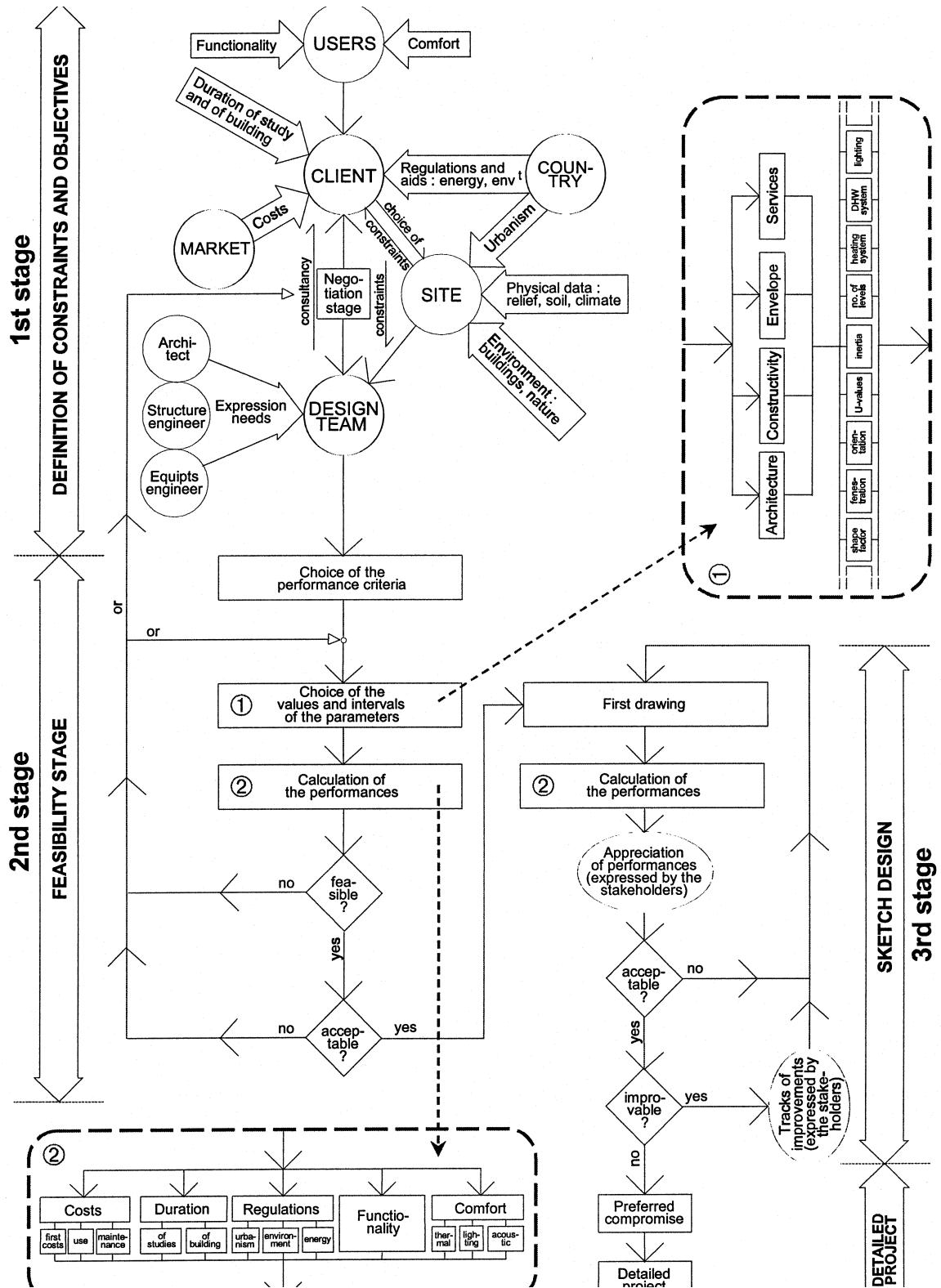


Figure 1 The preliminary stages of the design process.

second stage, the actors build several scenarios by defining parameters and assessing their values with some imprecision and tolerance; resulting performances are computed on the various selected criteria. This second stage is called the *feasibility stage*, because it results in two questions: (1) Is the scenario feasible? (2) Is the scenario acceptable to the stakeholders?

Loops are introduced in the process when negative responses are given to these questions until, entering the third stage, the actual *sketch design* becomes possible. After a first drawing of the project, performance calculations can be refined.

The stakeholders then judge these performances as acceptable or not and improvable or not.

Loops are envisaged in the case of nonacceptability or improvability, using a genetic algorithm procedure:

- Each actor is able to search for the optimal set of strategic parameters—which corresponding scenario gives the most satisfactory performances according to the criteria he/she considers as relevant.
- All the actors may try to find the preferred compromise, defined by the values of strategic parameters of which scenario gives the best performances to satisfy all the actors.

MULTIPLE ACTORS FEATURE OF THE BUILDING DESIGN PROCESS

The design process of a building is typically interactive, requiring the participation and mandatory satisfaction of several actors, each facing multiple criteria decisions:

- The *client* initiates the whole operation. The client may be the property developer, the owner, or a future occupant or user. He/she is increasingly involved in the design process and searches for design fitness to correspond to his/her requirements. Furthermore, the client's legal responsibility continuously increases, as does his/her responsibility in the building act. The client is personally responsible for the building's energy performance, environmental protection, etc.

Faced with these new duties, the client requests increased help from the design team. The project should allow the client to assume the new responsibilities, while reaching the objectives of cost, building period duration, comfort, and functionality. The client is considered, however, as having no technical capacity, so the software should ask soft questions, using familiar vocabulary.

- The *project author* is a generic term that more often designates the architect but also the consulting engineers (for structure, equipment, etc.), the quantity surveyor, the project manager, etc. The project author's mission is so heavy that he/she often neglects matters he/she considers as nonessential, e.g., the energy aspects. Though a

great deal of software is available to compute energy performance, it is, unfortunately, rarely used by architects in practice. Software should help project authors in their task, while maintaining their particular objectives, e.g., their expressed needs and wishes for increased notoriety.

- The *public authorities*, representing the country or the region, are authors of constraining lawful and normative standards (thermal, urbanistic, or environmental regulations, etc.). Some public policies are translated into constraining levels of energy performances.

Finally, we see that the goal of the MCDA process and the linked software is to help each actor express his/her particular needs, either in the form of constraints or multiple objectives, as well as to build an interactive tool capable of dialoging with each actor in his/her own language while providing useful performance indicators.

Every architectural project is progressively defined, necessitating frequent interrogations to the actors and making the corresponding adjustments (Conan 1989). The software should thus be able to allow for these frequent data adjustments.

Furthermore, when adjustments, which are essential to the project viability, are discovered too late in the design process or during the construction itself, they lead to additional costs, very often out of proportion when compared to their actual importance. Figure 2 gives an expression of the influence on the corollary adjustment cost of the decisions taken along a project, in function of the moment when they are taken (Ali Mohamed and Hens 1999).

A first feasibility check of the project is important in order to ensure that at least one solution exists. The feasibility study enriches the negotiation and/or incites the actors to negotiate the objectives and the associated means again, when the solution set is empty.

If a feasibility study is not mandatory, i.e., when the solution set is not empty, it may save time through a parametric definition of the project, which describes the relevant intervals of the main parameters and, especially, their robustness, i.e., performance stability to parameter variations.

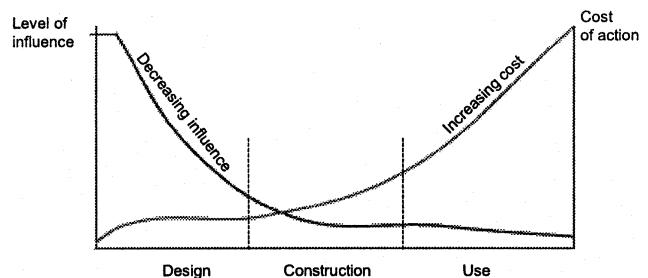


Figure 2 Influence of decisions taken during a project on their corollary adjustment cost, in function of the moment when they are taken.

While remaining very imprecise in the feasibility stage, project data may be sufficient to define a “scenario” (Roy and Bouyssou 2000; Maystre and Bollinger 1999) that characterizes the architectural choices and evaluates resulting performances.

AMCE SOFTWARE: AN INTERACTIVE TOOL FOR INTRODUCING TECHNICAL AND PREFERENCE DATA AND EVALUATING SKETCH DESIGN PERFORMANCE

AMCE is an acronym for “aid to the multiple criteria conception of the building envelope” (in French: *aide multicritère à la conception de l’enveloppe de bâtiment*). The software is an object-oriented program, developed in both French and English. It runs on a common PC, with minimal characteristics: a 120 MHz microprocessor, an operating system, 15 Mb hard disk capacity, 32 Mb RAM storage capacity (64 Mb recommended), and an SVGA graphic card with a palette of 64,000 colors. It is still in the prototype stage of development and must be tested by a panel of French architects before it can be distributed among architects.

The usual starting point in energy software is the drawing of the sketch design itself. This approach lacks a first parametric phase, which allows defining a set of feasible solutions, among them, the preferred choice (Crawley et al. 1998; De Wilde et al. 1998; Rivard et al. 1995). In our proposed design procedure, each actor chooses and manages the values of the *main parameters*, in order to satisfy selected criteria, based on individual preferences and requirements.

AMCE has been built to facilitate an interactive introduction of technical and preference data by each actor, based on individual needs and capacity, and to compute performance criteria.

Selected Criteria: Project Performances

The software evaluates performances with regard to energy aspects of heating, air conditioning, domestic hot water, and artificial lighting, as well as construction and use costs of the project:

- four regulation performances: *K-level* (as required in Flanders and Wallonia), *Be* heating energy needs (in Wallonia), *G/Gref*, *B/Bref*, *C/Cref* (in France);
- yearly energy consumption expressed in physical units (kWh) for heating and domestic hot water (DHW), air conditioning (HVAC), and artificial lighting;
- associated energy consumption costs, i.e., use costs;
- project construction cost, VAT and fees excluded.

Actor’s Preferences: Choice of Criterion Types and Thresholds

Anyone intervening in the building process (the architect, owner, tenant, property developer, etc.) can participate in its elaboration. Each actor defines a scenario summarizing his/

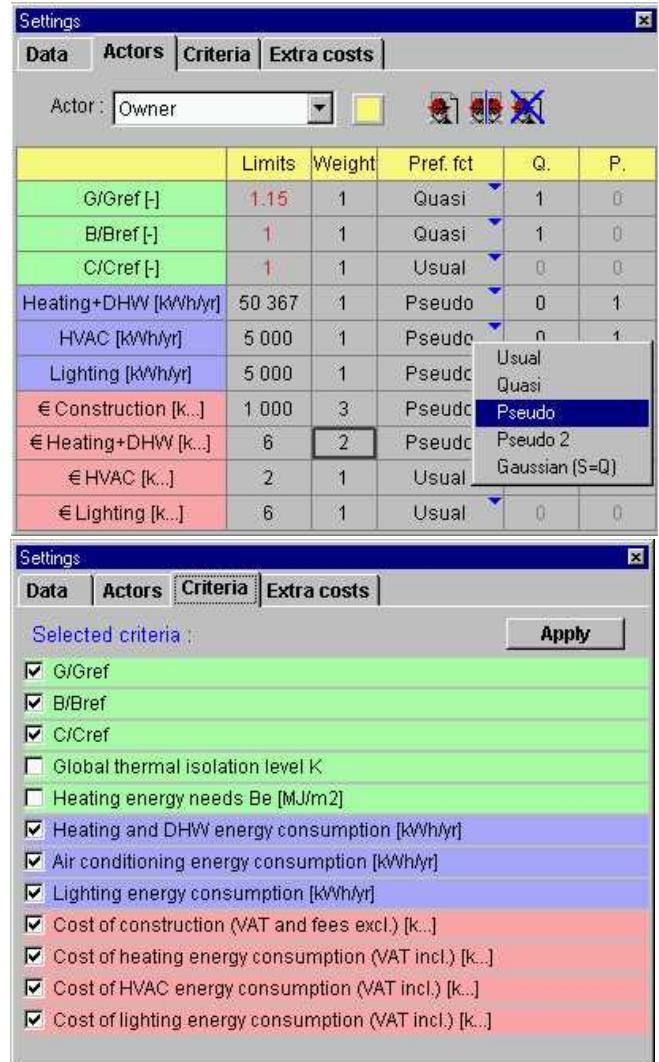


Figure 3 Actor’s preferences for criteria: the case of the owner—choice of relevant performance criteria.

her desiderata and requirements. With the button “actor’s preferences,” actors defines their preferences (Figure 3).

- They choose the background color that identifies them in all windows generated by the software.
- They choose the preferred monetary unit (Euro or the monetary unit of the country where the project is located).

For each criterion, they specify

- the maximum admissible critical value;
- an associated preference function, using the Promethee typology, as true (= usual) criterion, quasi-criterion, pseudo-criterion, etc. (Brans et al. 1986), as illustrated in Figure 4;

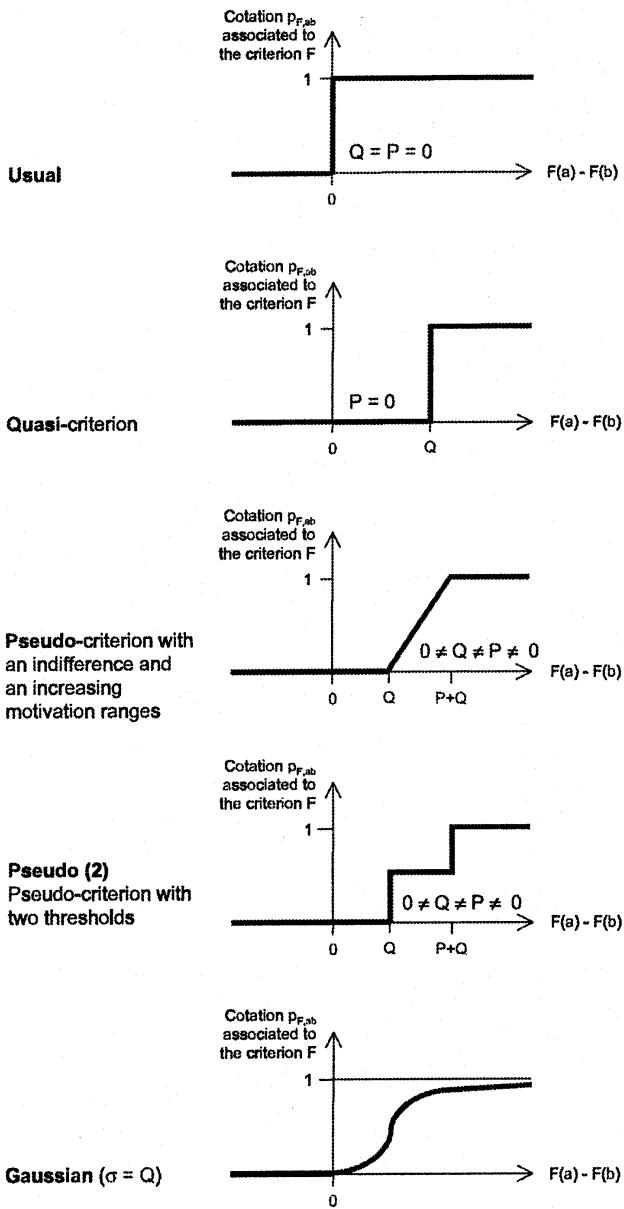


Figure 4 Promethee preference functions.

- thresholds P and Q of the preference function: if $P = 0$, this is a quasi-criterion, and if $P = Q = 0$, the criterion is true (\equiv usual);
- weights given to the criteria: corresponding to the Promethee multicriteria approach, a weight is like a coefficient of the importance the actor attaches to each criterion (Schärlig 1996). Each user allocates any null or positive weight to each criterion. The criterion receiving the highest weight is the most important one, while the criterion with the smallest weight is the least important one. The software gives each criterion the relative weight it has in proportion with the sum of all the

weights accorded to the criteria set. When an actor gives a null weight to a criterion, this expresses that the actor is completely indifferent to this criterion and considers it not interesting at all. Weight allocating is a personal, subjective matter depending on the value scale each actor feels on performance criteria.

Actor's Scenarios and Questionnaires for Data Introduction

An actor's scenario is a set of values the actor gives to the parameters he/she can understand and control. The introduced parameters are only necessary and sufficient to the preliminary performance estimates. At this stage of the project, prior to any drawing of the draft, the geometrical parameters replace the geometrical variables, which will be defined later.

The questionnaire is organized by items, i.e., thermal comfort, fenestration, solar aptitude, thermal characteristics of the envelope, equipment sophistication (to evaluate the efficiencies of heating and lighting systems), etc. In order to fit the technical capacity of the user, the collection of parameter preferred values characterizing the project uses a questionnaire, organized on two levels:

- A semantic level, fitting the client's technical capacity; it helps the client specify the demands and requirements.
- A more technical level is proposed to the project author, who defines the preliminary characteristics of the project by answering no more than 60 questions.

For example, a screen is proposed to the client (= owner), asking for the shape aspects he/she can define (upper part of Figure 5). The same question, but on a more technical level, is proposed to the project author (lower part of Figure 5).

In order to facilitate user questioning, all answers are previously filled in with default values and the user may modify them.

Of course, many parameters (and associated questions) may depend on other ones. For example, when specifying that the roof is a flat roof, the user does not have to answer questions about attics or roof edge; these questions are suppressed from the questionnaire and are not asked. But, if a positive (and not nil) angle is still chosen for the roof slope, these questions appear again and must be asked if default values are not in accordance with actor's wishes.

For each parameter, the following help will be provided on request, by right clicking the mouse:

- a more explicit definition of the parameter and
- values encountered in previous projects. The cultural approach of the project author is given here, in a database of projects already executed by him/her, with associated parameter values.

Peculiar attention has been devoted to the mutual parameter consistency. The choices of fenestration and shared external walls are an example. In the beginning of the questioning

The figure consists of two side-by-side screenshots of the AMCE 1.0 software interface. Both screens have a toolbar at the top with various icons, a left sidebar with a tree view of categories, and a main panel for data entry.

Top Screen (Client Geometry Details):

- Actor:** Owner
- Data:**
 - Net total habitable floor area: 100 m² ± 10%
 - Number of levels: 2
 - Tilted roof? (checkmark)
 - Habitable attic? (checkmark)
 - Seat of the lowest floor: Ground

Bottom Screen (Project Author Geometry Details):

- Actor:** Project author
- Data:**
 - Roof slope compared with horizontal: 35 deg ± 10%
 - Height under cornice: 3.70 m
 - Length: 2.70 m ± 10%
 - Height from floor to floor: 80 cm
 - Minimum height of the partition against the mini-attic: 1.30 m ± 20%
 - Elongation = Length/Depth of circumscribed rectangle: 1.00 m ± 20%
 - Bursting = circumscribed rectangle area / floor area on earth: 29 cm ± 10%
 - Thickness of external walls: Mean
 - Density of internal structural walls: Mean
 - Density of non structural internal partitions: Mean

Figure 5 Questionnaire proposed to the client (geometry) and to the project author (geometry: details).

This screenshot shows the AMCE 1.0 software interface with the 'Situation' category selected in the sidebar. The main panel displays the following data:

- Party portion of left gable:** 30.00 %
- Party portion of back facade:** 0 %
- Party portion of right gable:** 35 %
- Orientation of the main facade:** E
- Wind exposure:** Ex-1

Figure 6 Party portions of gables and back facade.

(see Figure 6), the general situation of the project is asked of the user, concerning the party portion of the gables and of the back facade. The main facade is considered as not having any area shared with any other heated volume.

The party portion default value is nil, which allows a uniform repartition of the glazed areas on all the facades (Figure 7).

The glazed areas are indifferently expressed in m² or in percentage of the project total glazed area (see Figure 8). The user is allowed to adapt the repartition of the glazed areas in the “solar details” management. When the user is modifying the glazed portions, a notice (see inset in Figure 8) warns that he/she must adapt the distribution of the glazed areas to the party portions previously defined.

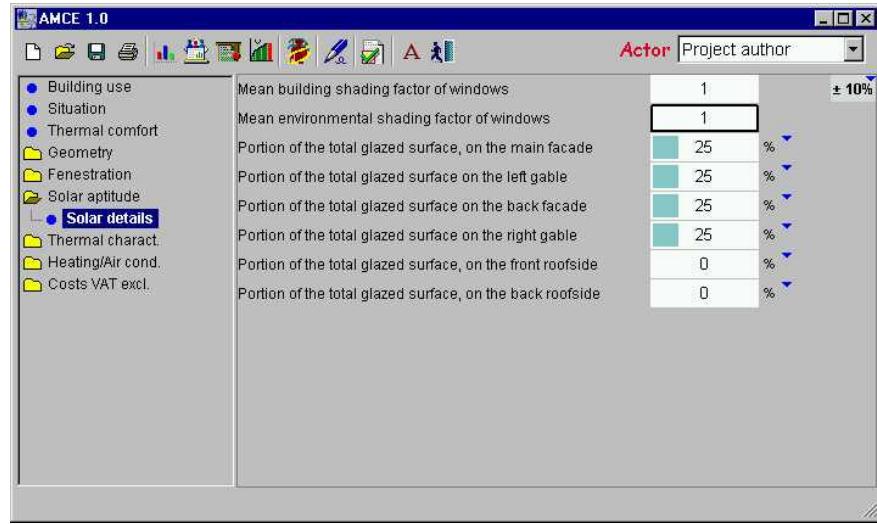


Figure 7 Default fenestration distribution.

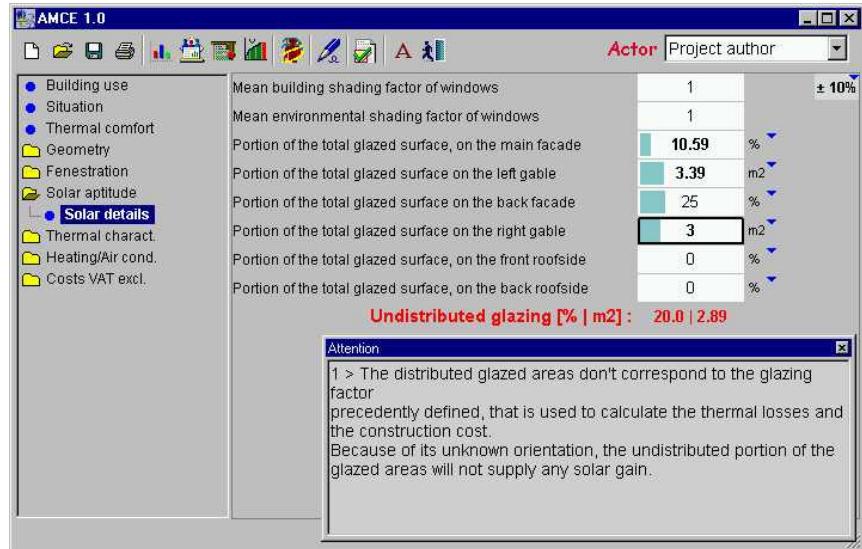


Figure 8 Correction of the fenestration distributed among the facades.

For strategic parameters, each actor specifies the accepted interval in which the parameter could vary. The actor thus chooses one tolerance interval level for each strategic parameter, according to his/her degree of certainty and/or his/her degree of requirement. Five different levels of “tolerance” intervals are proposed to the actor for this chosen value (see right-hand side of Figures 5, 7, or 8):

50%, 30%, 15%, 5% around the chosen value or no tolerance (fixed parameter).

“No tolerance” corresponds to a parameter prescribed by conditions outside the project and that cannot be changed by the design team.

Sometimes, one or both limits of the chosen interval is/are technically prohibited. In this case, the software introduces the

largest technically feasible values within the preferred interval. This tolerance interval mechanism is crucial for further performance sensitivity analysis and for the improvement step. If an actor enlarges intervals so that they are just limited by technical intervals, this may increase the set of admissible scenarios, e.g., the feasible decision space. Each time the actor reduces the intervals, the decision space is reduced accordingly, as well as the degree of improvement he/she may hope for in the next stage.

Displaying and Specifying Scenario Performances

A specific window (see Figure 9) lists the energy and cost performances obtained by all the scenarios defined by the actors (in bold: the actor currently using the software). Note that any actor can try more than one scenario.

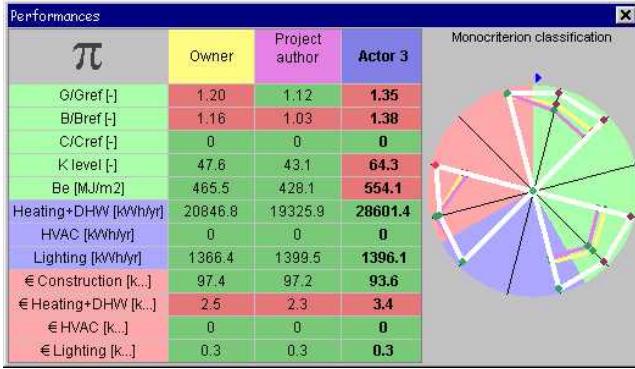


Figure 9 Performance window.

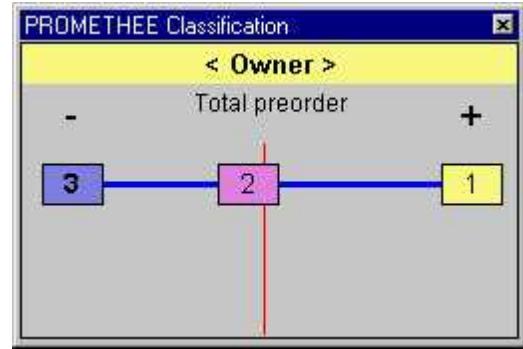


Figure 10 Promethee total preorder of the scenarios.

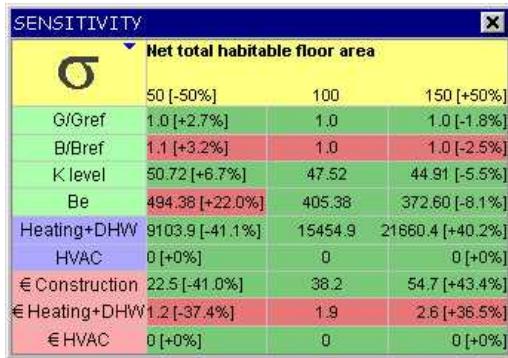


Figure 11 Window showing performance sensitivity to the variation of net total habitable floor area around its central value, 100 m².

In order to clearly display the satisfaction reached on the criteria specified by each actor, the background color of each result cell is displayed: green when the performance is satisfactory for the actor and red when it is not.

In Figure 9, for instance, the “Owner” is satisfied with all the performance values, expecting that the scenario is unacceptable on the French G/Gref and B/Bref coefficients, the cost of energy spent on “Heating + DHW.” The right column of Figure 9 displays the relative classification of scenarios for each performance in a monocriterion approach.

Figure 10 presents a Promethee total pre-order of the scenarios. The owner’s (or client’s) scenario (#1) is globally the best, while the project author’s scenario (#2) is less good, and the third actor’s scenario (#3) is the worse.

Sensitivity Analysis Performed by AMCE

The software calculates the performance variation for the criteria considered by the actors according to the parameter variations, thus guiding the project author toward an improved solution. The sensitivity of a chosen performance to the variation of one or two parameters can easily be obtained.

First, AMCE produces the σ performances for each chosen tolerance interval of the parameters and for each actor. For example, for each criterion, Figure 11 displays the perfor-

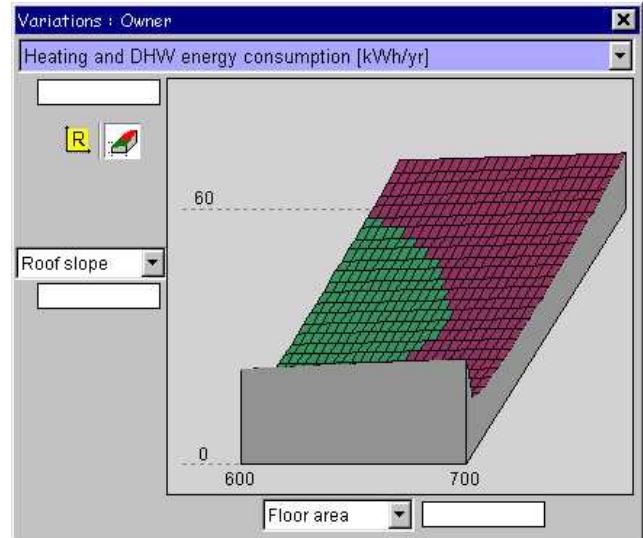


Figure 12 Some performance sensitivity to the variations of the floor area and the roof slope (three-dimensional graph).

mance interval produced by the interval of values ($\pm 50\%$ tolerance) of the net total habitable floor area around its central value (100 m²). The construction cost is 38.2 k for 100 m²; it increases 43.4% for a 50% increase in area, reaching 54.7 k , while a decrease of 50 m² produces, *ceteris paribus*, a fall of 41% for a new amount of 22.5 k . On this exemplary display, we observe that some values are presented in a red cell: f.i., making variations of 50% of floor area becomes a prohibited scenario for the criteria B/Bref and still remains unsatisfactory relating to yearly “heating + DHW” energy cost, of course.

Figure 12 (three-dimensional graph) and Figure 13 (two-dimensional graph) give the variation of the performance “energy consumption (in kWh) for heating and domestic hot water” to both continuous and technically acceptable variations of the net total habitable floor area and of the roof slope together; all other parameters remain unchanged at their decided central values. When the user clicks anywhere in the two-dimensional graph (Figure 13), he/she can obtain the corresponding values of floor area and roof slope; with the

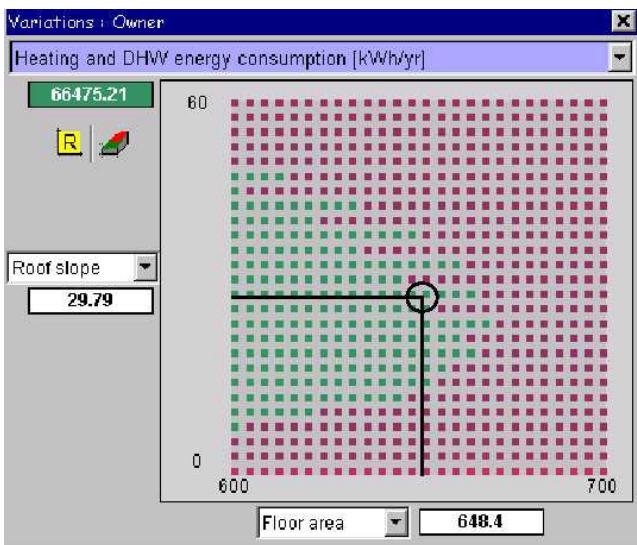


Figure 13 Some performance sensitivity to the variations of the floor area and the roof slope (two-dimensional graph).

performance obtained by this pair of values, all other scenario parameters remain unchanged.

At the end of the feasibility study, before any drawing has been made, two possibilities exist:

- Actors know the certain existence of at least one solution, as defined by the satisfactory parameter scenario. In this favorable case, they also know the sensitivity of the performances to the different parameters. This information can be useful to arbitrate the divergent choices or possibly to improve the design.
- If they are not able to find a scenario leading to acceptable performances, the sensitivity analyses largely document the negotiation that must follow evidence of an empty set of solutions. Negotiation then attempts to relax the most sensible constraints.

Therefore, this first stage goes beyond a simple feasibility study, which would only show whether or not a solution to the architectural problem exists. Defining a set of solutions, this parametric approach also locates a scenario space where the preferred feasible choice exists. The combination of parameter intervals of validity/tolerance indeed defines a solution space, which respects the criteria considered as relevant. Definition of this solution space is essential for the strategy of future project improvement.

Optimization Procedure to Reach Optimal Scenario Corresponding to Most Efficient Project

With an optimization procedure using a genetic algorithm, the software generates a random population of individuals. Each individual is a combination of possible values of the strategic parameters, among the eight billion possible combi-

nations resulting from the authorized values of the 13 (up to now) strategic parameters within varying intervals the actor has previously chosen. Each “individual” is a 13-position vector where each position represents a strategic parameter.

The optimization process is organized as follows:

1. A first population of individuals (the size of which is chosen by the user) is randomly generated.
2. The fitness f_x of each individual x is calculated using:

$$f_x = 1/d$$

where d is like a “weighted distance” to optimal performance in the 13-dimension space of solutions:

$$d = \sqrt{\sum_{i=1}^n \left(\frac{P_i}{C_i} \cdot W_i \right)^2}$$

where

P_i = performance obtained relating to criterion i (all performances are to be minimized);

C_i = maximal authorized (or wished) value related to criterion i ;

W_i = weight allocated to P_i ;

n = number of criteria.

3. Statistical evaluations—maximum, minimum, and mean fitnesses—are calculated. If the maximum fitness is larger than the absolute best (obtained up to now) individual’s fitness, the individual corresponding to the maximum fitness is saved as the absolute best one; otherwise, the previous absolute best individual is kept.
4. The optimization process is stopped if the maximum number of generations is reached or if the absolute best fitness increase over several generations is too small, so that the convergence is considered obtained.
5. The population fitnesses are scaled in order to avoid any premature convergence, i.e., any local optimum.
6. Reproduction loop:
 - Selection procedure: fitnesses are distributed on a pie and Russian roulette randomly selects a fitness, with a greater chance to come across a high fitness; the corresponding individual (parent) is selected by the software and a second one in the same way.
 - The crossover operator is applied to the selected pair of parents, giving children individuals.
 - The mutation operator is also applied to children individuals resulting from crossover.

A new population of new individuals is so obtained. The process returns to step 2 (fitness evaluation).

The software finds the best combination of strategic parameter values (Figure 14) that, in fact, generates the most efficient scenario whose performances are the most satisfactory in accordance with the actor’s preferences.

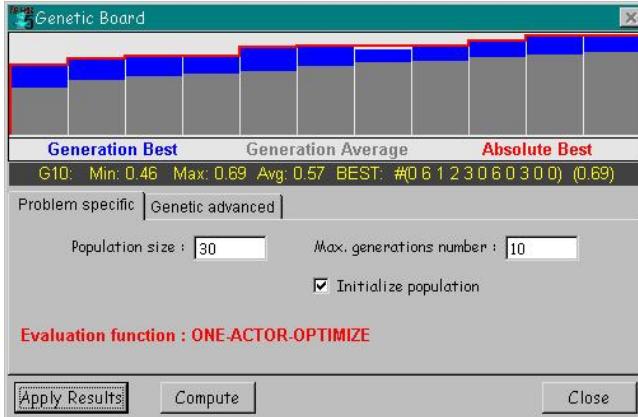


Figure 14 One-actor optimization using a genetic algorithm.

In this monoactor optimization, the actor's satisfaction is the convergence rule of the genetic algorithm.

In Figure 9, the third actor's scenario gave the worst performances when compared to the other ones. After the optimization, the new third actor's performances (displayed in Figure 15) have been largely improved. Not only G/Gref and B/Bref are now acceptable, but all this scenario's performances are better than those obtained with the other scenarios, even for the “heating + DHW” energy cost, remaining beyond the admissible value previously defined by Actor 3.

Multiple Actors Optimization Procedure to Reach the Most Preferred Compromise

All the actors concerned by the project may find their most preferred compromise by using the multiple actors optimization procedure. This optimization routine is similar to the monoactor one except for its convergence rule: the software must search for the scenario with

- the best performances possible and
- the most equal satisfaction for all actors. When a project obtains good performances but gives actors unequal satisfaction, this project's further life is threatened by the unsatisfied actor(s).

Before the procedure, a checking routine displays the parameter(s) conflicting with actors, i.e., the parameter(s) whose actors' authorized intervals have no intersection (Figure 16). When it happens, one can say that these scenarios are not comparable, so that any preferred compromise does not exist. The conflict parameters must be first negotiated between actors before any optimization.

In this way, the individual fitness f_x is defined differently than in the monoactor procedure:

$$f_x = \frac{1}{d_{max}} \cdot \frac{1}{(d_{max} - d_{min})}$$

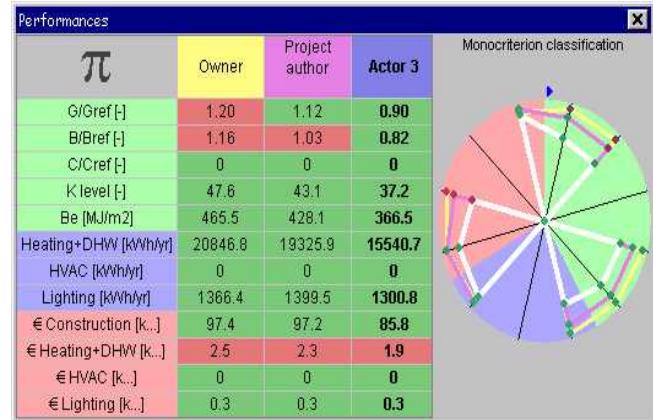


Figure 15 Optimized performances of the third actor's scenario.

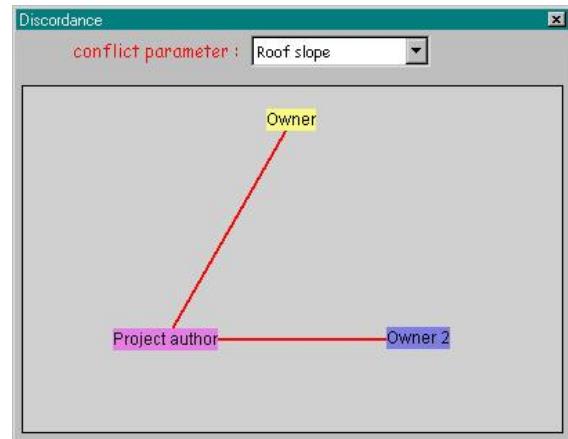


Figure 16 Display of conflict parameters (here the floor area) between the owner and the project author whose choice is similar to the third actor's.

where d_{max} is the maximum value (the worst performance) encountered in d_{aj} values related to actors a_j , and d_{min} is the minimum d_{aj} value. The fitness optimization has two parallel objectives corresponding to the two terms in the f_x expression:

- maximizing the performances is as similar as minimizing their maximum weighted distance (d_{max});
- equalizing the actors' satisfactions is the same as minimizing the difference between d_{max} and d_{min} values.

SKETCH DESIGN: DRAWING THE FIRST DRAFT AND PERFORMANCE EVALUATION

The third stage of the decision process will allow a sketch design, but, at any time, the drawing of the first draft could be realized by the project author using the EsQUIS-E module developed in LEMA (LeClercq 1999).

The EsQUIS-E software is an experimental computer-based prototype interface for capturing and interpreting the

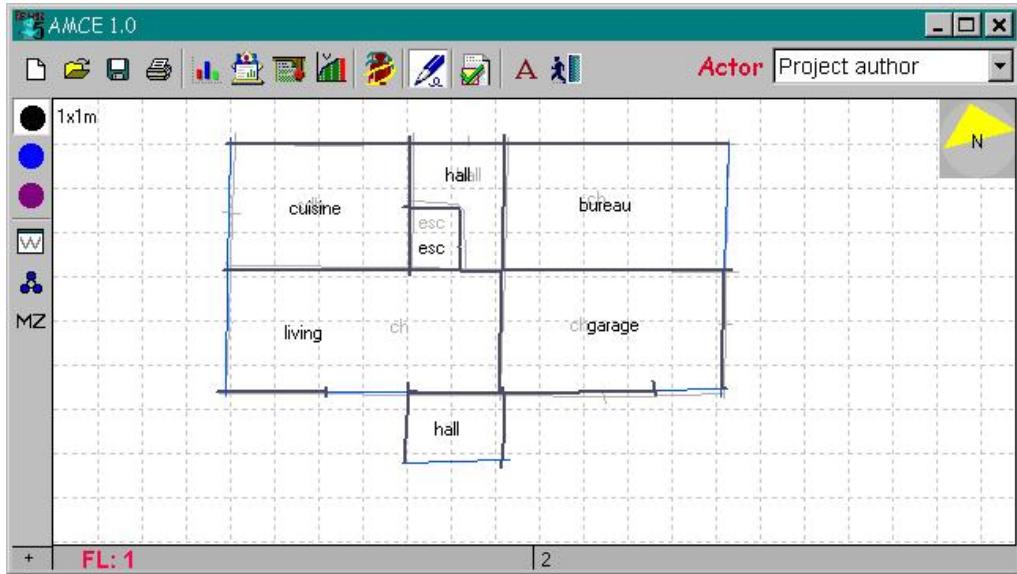


Figure 17 Original sketch (ground floor) drawn on a digital tablet or with the mouse.

architect's sketch by locating its architectural concepts: border line, functional space, and topology. The aim of this prototype is to compose a spatial semantic representation of the architectural project in order to feed diverse computer architectural design evaluation routines and serve as a tool with interface that complies to the designer's working technique. The EsQUIsE pen-based module performs the capture and the synthesis of the lines drawn on the digital tablet. These lines are drawn in black (opaque walls), blue (glazed walls), or magenta (comments) (see Figure 17).

The project author names the functional spaces. On this basis, the program fixes the characteristics necessary for the evaluations. For example, the default comfort temperature assigned to each occupied space is fixed according to its function: 18°C for the kitchen, 24°C for the bathroom, etc. It may be changed if the user prefers another value.

By studying the contacts between the synthesized lines, EsQUIsE sketches the spaces to be occupied (Figure 18). Several procedures then deduce the topological relationships of the described architectural project (see Figure 19).

The advantage of using a man-machine interface based on the semantic analysis of an architectural sketch is that one is spared the measuring work of the architect's blueprint. Instead of the two or three days usually required to measure and encode, energy and cost performances are supplied directly after the drawing of the last line of the sketch. On the other hand, it avoids any accidental wrong numerical values that could be input by human user.

This drawn support constitutes a preliminary basis for discussion with the client, whose understanding requires a graphic expression. This constitutes the only means of checking how well the project corresponds to the client's desiderata, including implicit ones (nonverbalized). This first response is already rich, particularly with regard to evaluations.

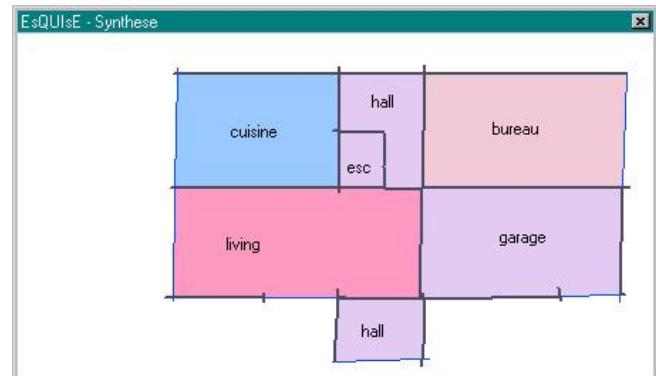


Figure 18 Synthesized sketch of the ground floor.

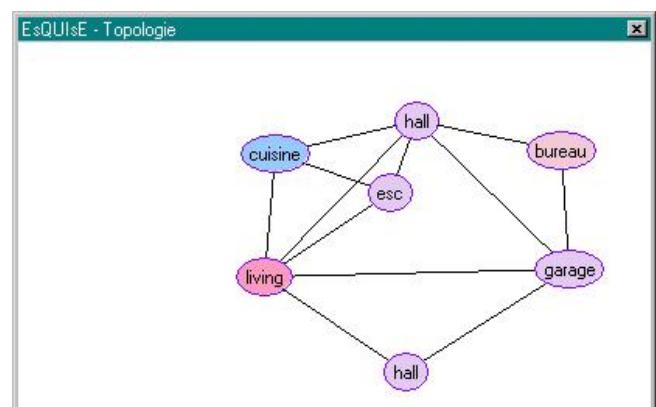


Figure 19 Space topology of the ground floor.

The application tested in the late stages of EsQUIsE is a classical module MZS (for multizone stationary) also previously developed in LEMA. It makes the multizone evaluation of the building's energy needs, taking internal and solar gains into account (see Figure 20).

After the drawing of the draft, the user can go back to the parameter module, where geometrical data previously defined are replaced by the ones generated by the drawn sketch (Figure 21). Other thermal or economic data of the questionnaire are unchanged.

The same evaluation routines check project performances of the drawn project, which are displayed in the performance window:

- either the performances are reached,
- or the performances are not reached. Any actor could try to satisfy each requested performance by using the parameter sensitivity analyses or the optimization procedure. In the case of a conflict between performances reached and performances desired, a negotiation would be initiated in order to refine objectives and parameter values.

Espace :	Jan	Fev	Mar	Avr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
* Besoins energetiques des locaux chauffés (W):												
Cuisine	680	593	436	242	53	-63	-93	-72	62	293	553	684
Sejour	1315	1150	820	375	-86	-327	-374	-288	49	548	1063	1319
Esc	9	4	-8	-27	-49	-64	-70	-68	-54	-31	-7	8
Ch	-9	-11	-17	-27	-39	-47	-52	-51	-44	-32	-18	-9
Hall	-4	-5	-7	-12	-17	-21	-23	-23	-20	-14	-8	-4
vC	81	64	31	-15	-81	-88	-94	-86	-51	0	54	81
Hall	-30	-171	-378	-599	-805	-932	-969	-964	-834	-552	-195	-15
Ch	-12	-14	-23	-36	-53	-65	-70	-70	-61	-44	-24	-13
Ch	-9	-11	-17	-27	-39	-48	-52	-52	-45	-32	-18	-9
Sdb	560	540	497	436	369	327	315	324	370	441	518	558
Bureau	248	228	188	133	76	40	31	38	78	142	211	247
Ch	-11	-13	-21	-33	-48	-59	-64	-63	-55	-40	-22	-12
Ch	655	477	95	-444	-1021	-1388	-1500	-1423	-1028	-399	284	644
Besoin de chauffage = 14139												
Besoin de climatisation = 12594 Ventilation MINIMALE												

Figure 20 Monthly and yearly heating (and cooling) energy needs of the drawn sketch.

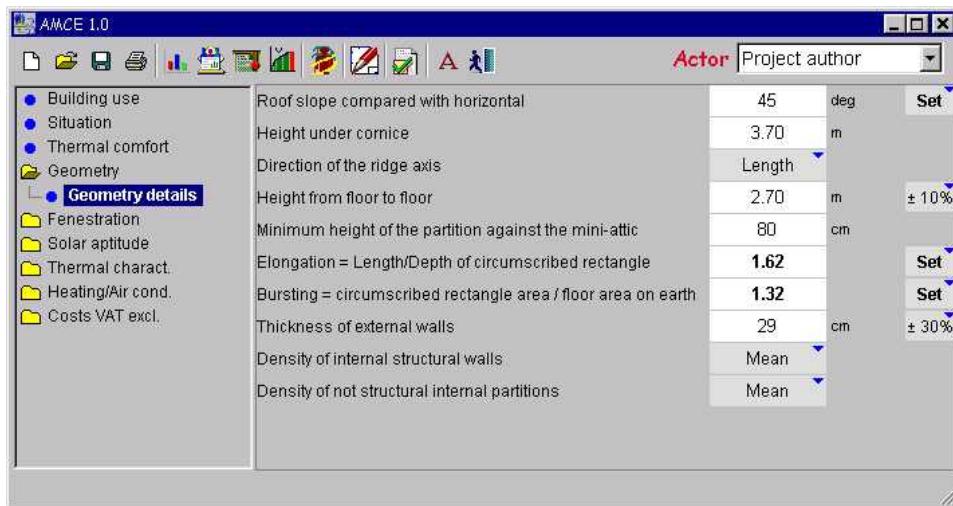


Figure 21 Geometrical data replaced by the ones resulting from the sketch drawn with the EsQUIsE module.

The project author presents the draft to the client, who is now able to react and intervene on parameters and desired performance values.

Improvement (and/or optimization) of the draft, by its iterative modification and/or by the drawing of new drafts, will take the procedure back to the previous stage.

CONTINUATION OF THE PROJECT DESIGN

The result of the feasibility stage is a sketch whose parameters, accepted by the different actors, give the best performances. It circumscribes the most efficient choices related to the energy and cost performances of the future building.

It now constitutes the project basis to be used in the continuation of the design process during the detailed design, which falls under topics currently developed and commonly used in architecture.

CONCLUSION AND FURTHER ADVANCES OF THE SKETCH DESIGN TOOL

With respect to usual architectural practice, our new methodology provides the following advantages:

- It alleviates the work load of the project author and increased energy and cost performances of the project.
- It supplies a multiple criteria decision aid for elaboration and negotiation of a preferred compromise between the several actors.
- It gives enhanced help to the client within a difficult technical context, where his/her responsibility is increasing, especially regarding environmental regulations.

In conclusion, the final product will be used to interest more architects and help them in building energy performance, both a present and future ecological concern.

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