# Interaction between qualitative and quantitative approaches in the teaching of architectural design

**Ljubica MUDRI***

Ecole d'Architecture Paris-Conflans, Laboratoire EVCAU
11 rue du séminaire de Conflans, 94220 Charenton le Pont, France
Email : lenard@lamsade.dauphine.fr

**Abstract**: In order to improve the understanding of daylighting by students in architecture, we seek a better integration between scientific and architectural languages and we try to strengthen the links between quantitative (knowledge on daylighting as a physical phenomenon expressed in mathematical terms) and qualitative (knowledge on daylighting as a modifier of luminous ambiance expressed in a descriptive way using natural language). This will help students to reach a better control of the phenomenon, to build their own criteria and to apply them in the sketch phase of architectural design. It may also be a basis for a aiding-system for the design in the sketch phase. We used fuzzy set methods and multivalued logicsto model the building and its environment and to structure knowledge taking architect's preferences into account.

## 1. Introduction

When teaching to students in architecture how to master ambiances, it is important to make them aware of the fact that physical and technical constraints are inseparable from the architecture of the building and of the environment. Taking into account technical problems is not independent from the artistic design process. With experienced architects, this is nearly implicit. Apart from explicit constraints, their experience, knowledge, an intimate set of criteria help them detect fundamental requirements which will determine the project spirit. Conversely, students are building their set of criteria. During the exercises in design, they also choose the most important criteria among those they have. However, they have fewer criteria at their disposal and these do not represent a synthesis of the possible ones. Hence, students often see Architecture and Physics as separated topics: interesting concepts for a lecture in Acoustics or Daylighting become suddenly irrelevant in the design of projects and are therefore not used.

In our view, this is due to the differences in the embedded aproaches. On one hand, it is our belief that, in architectural design, fundamental choices are taken during the sketch phase. Validations of these decisions by the architects also occur in this phase where they validate their architectural intentions. The architects' approach is rather intuitive, qualitative and descriptive and data in a sketch are imprecise and incomplete [5]. On the other hand, validation of the technical qualities of buildings by experts with sophisticated classical techniques for the occur in the

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detailled design phase. This approach is quantitative and the mathematical methods use precise and complete data which are available *only at the end* of the design. Therefore, students who learnt to evaluate qualities of ambiance in a quantitative way cannot evaluate quality of ambiance, that is apply their knowledge in the sketch phase as, in this situation, they have to reason in a qualitative way.

To solve the problem, we have dealt with a number of both theoretical and methodological questions we shall present below.

*Our hypothesis* is that the main choices for the concept are taken in the sketch phase of architectural design. It is true that, in practice, design goes up to the building works. However, fundamental choices for the project are determined in the sketch phase.

For us, a sketch is a materialised image of the architectural object represented in an imprecise and incomplete manner. The following example illustrates one of the possible precision levels for the project.

Figure 1. Example of a project sketch

*Our objective* is therefore to model knowledge about luminous ambiance in a way both usable and understandable way in the sketch phase. The knowledge may then be used as a basis for the teaching but also for an educational system.

This system evaluates, on one hand, the quality of luminous ambiance on an architectural sketch according to architectural intentions (as litterally expressed by the student) and, on the other hand, it offers access to the knowledge structure in order to facilitate the understanding of the results.

## 2. Classical evaluation methods

A well-known technique is the one using the daylight factor $F_j$ (ratio of the illuminance at the considered point to the exterior illuminance on an horizontal plane in an open site). This factor $F_j$, expressed as a percentage, is a sum of three components: a direct component corresponding to what is directly received from the sky, an exterior reflected component corresponding to what is received from the environment and an interior reflected component which is a consequence of the inter-reflexions in the interior space. The knowledge of $F_j$ for a large number of points gives the photometry of the space. Let us note that, in order to express the direct and exterior reflected

components of $F_j$, it is necessary to know *exact* surfaces and glazing types of every opening. However, these data are precisely defined at the end of the project, not during. Moreover, data already defined in the sketch phase (orientation, site) cannot be used as they are combined with unknown data.
Building on this, computer systems based on quantitative methods allows to simulate levels of distributions for illuminance, luminance and $F_j$ with precise and complete data. Hence, according to our objective, our system cannot be a simulation tool because of the imprecision and incompleteness of the data during the sketch phase and, of course, because one needs results in real-time during the design.

## 3. Our method

To be able to progressively evaluate data relative to room ambiance, we have grouped criteria according to the origin of data and to design evolution. Let us show as an example a branch of this grouping: the facade branch.

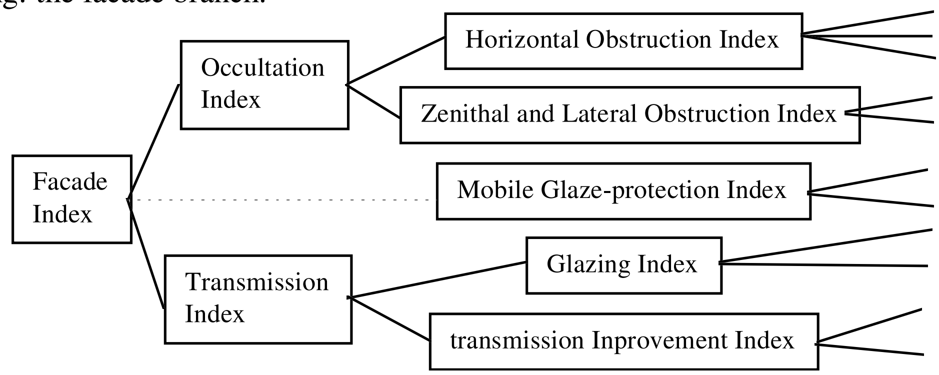

Figure 2. Example of a branch of indices for the basic state

Branches relative to the environment, the facade and the interior build a complete structure of criteria (the basic state). We may then derive (from the basic state) specific states with specific semantics. One may consider a specific state as a higher level of language closer to the language of architectural design and it is in these terms that students express their intentions. Entities of a specific state are always explained in terms of the basic state and this is how links are maintained between qualitative and quantitative approaches.

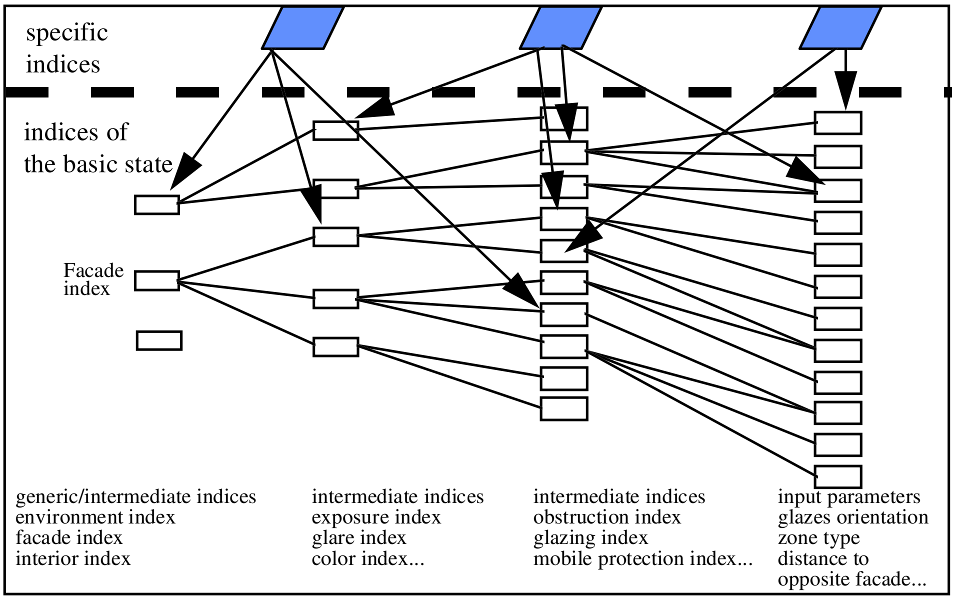


Figure 3. Global structure of indices

For example, let us consider the dynamism of luminous ambiance as a specific state in the structure. We have described this state on the scale: very dynamic, dynamic, rather dynamic, rather calm, calm, very calm. We have expressed this state as a function on the following specific indices:

- Type of penetration of natural light (importance of shadows) which refers to the basic indices: exposure, close obstructions and index for mobile glaze protection (values: bright, rather bright, average, rather dark, dark).
- Global distribution of natural light which refers to the basic indices: general distribution of openings per room and index for room morphology (values: uniform, rather uniform, average, rather non-uniform, non-uniform).
- Range of contrast: index for contrasts of illuminance and index for surfaces around openings (values: very smooth, smooth, rather smooth, rather strong, strong, very strong).

This state may be assessed according to three states of sky [7, 8] (overcast, intermediate and clear) and three seasons (summer, winter and intermediate).

We present here a few examples of rules which determine the values of the indices in the specific state:

The *darker* the penetration of natural light and the *more uniform* the global distribution of natural light and the *smoother* the range of contrast and the *more overcast* the sky then the *calmer* the ambiance.

The *brighter* the penetration of natural light and the *more non-uniform* the global distribution of natural light and the *stronger* the range of contrast and the *clearer* the sky then the *more dynamic* the ambiance.

## 4. How is it used during the design ?

The starting point for an evaluation is a sketch of the project and the intentions expressed by the student about the specific indices. Then, the system evaluates the project. It is not an absolute evaluation but one relative to the intentions [3, 4] of the student (does he wish a rather calm or dynamic ambiance?). It is also based on experts' rules and basic data (what ambiance may result from the physical properties of the building in a particular environment?). In that way, the student receives different information concerning the luminous ambiance during the design. The information level is adapted to the evolution and precision of the sketch.

The first information shows what may happen just outside the window, more exactly on the outside surface of each window of the room in an open site. More precisely, this information expresses illuminance levels just outside the windows from all origins; it also indicates the origin of lighting, that is from which part of the sky does the light comes in real weather conditions but without taking obstructions into account. The results are expressed in terms of frequency for the different illuminance levels and in terms of penetration of direct light and importance of this penetration (duration and solid angle). The objects of the building and of its environment related to this information are: glazing orientation, geographic location and glazing slants (which constitutes the exposure index), reflexion from the ground and the prospect (which constitutes the context index) and zone type, glazing slants and access to glazing (which forms the index for soiling).

The student then see to what extent his intentions for the interior ambiance are compatible with the data from the environment.

In a second step, we may also take into account data (still imprecise) about elements from the facade and the room geometry (Figure 2.).

Figure 5. Example of results for the architect

Evaluations of the project according to the intentions (for example, rather clear or dynamic) present illuminance zones on the working plane (that is the plane covering the ground at 0.8 meter height) and the walls. From the frequencies for the illulinance levels per zone, the system analyses the uniformity of lighting and the contrasts to calculate a degree of compatibility between the intention (rather clear or dynamic) and the result calculated from the sketch. The results shown on figure 5 correspond to a room situated in Paris with depth index[1] 1/2, glazing index[2] 1/3, orientation North and position of the glaze as shown on figure 1.

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[1] Depth Index $I_p$ is the ratio of facade height to ground depth.

[2] Glazed Surface Index $I_{sv}$ is the ratio of glazed surface of the facade to ground surface.

The results on figure 5 show that: in the clicked zone, due to natural light it would be very dark during 13% of the time (less than 100 Lux), dark 40% of the time (100 to 200 Lux), rather dark 40% of the time (200 to 300 Lux), rather clear 7% of the time (300 to 400 Lux). There is no penetration of direct light from the sun. The analysis of contrast shows that ambiance is not dynamic but rather calm and rather bright in zones 1-6 and rather dark in zones 7-9.

## 5. How does the system calculate illuminance levels frequencies ?

We built a data base and a knowledge base from the results of a structure of cases[3] we simulated. Examples of results are presented on figure 6 to show the overall approach.

The simulations have been performed for glazing index 1/2, 1/3, 1/4, 1/6, 1/8, 1/10. It gave us curves which shows illuminance levels for each zone (at a given time). Building on it, we obtain illuminance levels (or frequencies per year as on figure 5) for any $I_{sv}$ ranging from 1/2 to 1/10 (for example for 1/5.3, value of A on figure 6). Moreover, the system may calculate illuminance levels for imprecise $I_{sv}$, for example between 1/3.5 and 1/4 (refer to possibility distribution on surface BCD on figure 6 and [6]).

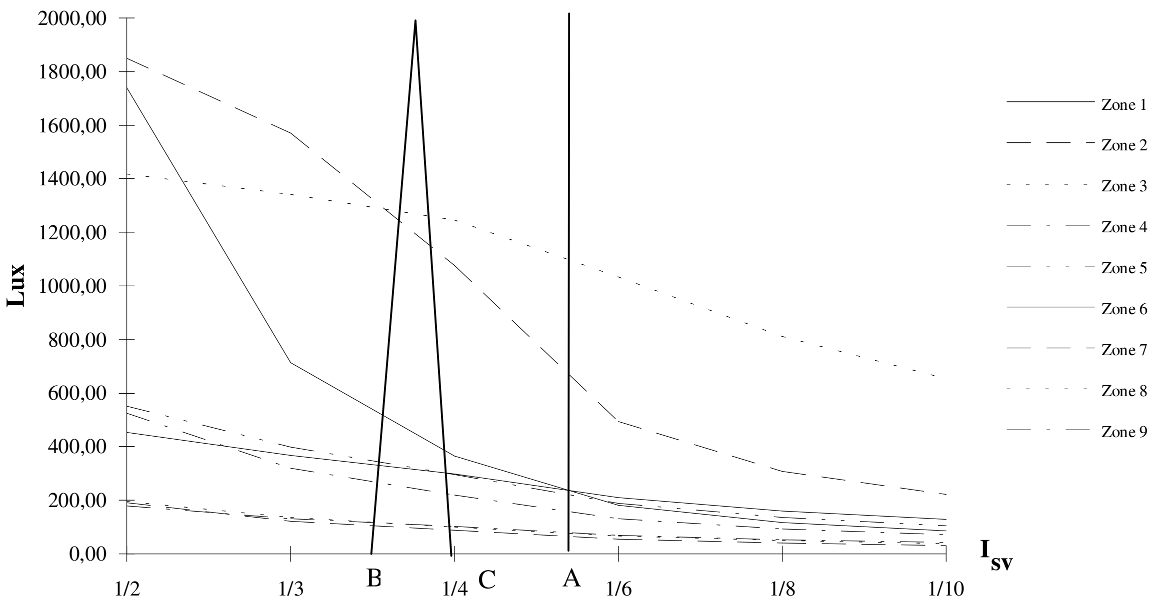


Figure 6. Illuminance levels for each zone

In this structure of cases, there are, therefore, some cases for which illuminance values are known “boxes with values” (calculated by simulation) and other cases “empty boxes” (not calculated). If we are interested in a case whose box is empty, the system will approximate the value (as shown for point A and for an imprecise point between B and C on figure 6).

## Conclusion

[3] Building models for natural light point of view, refer to Mudri L., Aide à la conception de l’éclairage naturel dans la phase d’esquisse architecturale et son impact sur l’énergétique, Ecole des Mines de Paris, (to appear)

Up to now, our system is able to show sketch evaluations for parallelepiped rooms (any dimensions) for any positions of the windows. The evaluations are relative to the intentions of the students. The system never proposes a solution or another sketch because we consider that it must be a computer-ading design tool and not a computer-making design

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13% very dark
40% dark
40% rather dark
7% rather clear