Environmental design of a building

Climatic context

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ABSTRACT: This article concerns the climatic context related to the environmental assessment of projects at their preliminary phase of design. An evaluation method is proposed, which is based on the definition of objectives and assessment criteria, as well as on the introduction of a "contextual weighting" system. These weights allow us to adjust the evaluation of various issues related to the "climates" of each project.Our purpose relates here to the identification of climatic data influencing the evaluation criteria in order to define context coefficients.

Keywords: Environment, assessment methods, climatic context, architectural design.

1. INTRODUCTION

The issue of sustainable development and more precisely related environmental matters are key stakes to consider in buildings, and more particularly in architecture.

Evaluation methods of environmental quality are currently recognised as mandatory in these design approaches. However, the concept of quality cannot be defined abstractly and must be connected to a context and more particularly a climatic context.

This is why we set up a contextual assessment method for buildings environmental quality, in order to assist the work of architectural design. It has three characteristics:

- It is based on a global model defining environmental criteria used in the evaluation process;
- It is adapted to the different phases of architectural design;
- it takes into account specificities of each operation.

This article presents the development of the third point, the taking into account of specificities of a project and more particularly specificities in terms of climatic context.

The proposed method allows us to adapt the environmental assessment to the specific climatic context of each project by using a weighting criteria called "context coefficient".

Firstly, we propose a climatic classification adapted to the design process.

Secondly, we define a first version of "context coefficients" based on this classification.

And finally, we validate this weighting system by a survey conducted on architects.

2. CLIMATIC CLASSIFICATION

2.1. Definition

The climatic context can be defined by the description of the weather conditions of a given area which can be established using various data such as: temperature, pluviometry, amount of sunshine, humidity, etc.

Classifing climates therefore consists of organizing these data, in homogenous zones of similar climates. The data taken into account for this classification depend on the goal and the required precision.

This second part presents some classification examples, differing in terms of goals and required data.

2.2. The Köppen classification

The Köppen classification was put forward by Wladimir Peter KÖPPEN in 1920 [1]. The data required to use it are precipitations and temperatures. The method has three stages, within each of which different climatic definitions are used.

The first stage characterizes five climate types (Table 1). They are identified by temperature and pluviometry characteristics.

Table 1 : 1st stage of Köppen classification.

code	Climate types
A	Equatorial
B	aride
C	warm temperate
D	snow
E	polar

For example, the "warm temperate climate" is defined by :

- The average temperature of the three coldest months between -3 °C and 18 °C;
- the average temperature of the hottest month above 10 °C;
- seasons, summer and winter, must be well defined.

The second phase refines this first characterization according to the pluviometric regime. And similarly, the third stage specifies the annual temperature variations.

For example the climate classified as "Csa", representing the Mediterranean climate has the following characteristics:

- Climate type: moderately hot;
- pluviometric regime: precipitations between 380 and 760 mm;

- temperature variations: hot summer.

The final proposal contains about thirty climate classes, identified by and organized in codes of two or three letters, which correspond to the three stages of the classification system. This method allows a precise and detailed climate characterization.

This system was refined little by little. The current version is that presented by Rudolf GREIGER in 1961. This classification remains a reference thanks to regular updates in the fields of hydrology, geography, agriculture and in the study of climate changes.

2.3. Holdridge Life Zones System

"The holdridge life zones" is a method of climatic classification published by Leslie HOLDRIDGE [2], that relates climates to their associated vegetation types.

This classification is shown as a triangle for which each axis represents a climatic factor (refer to fig. 1), precipitations, humidity, and the ratio of the potential of evapotranspiration. The system also integrates three other indicators, namely biotempérature, altitude and latitude.

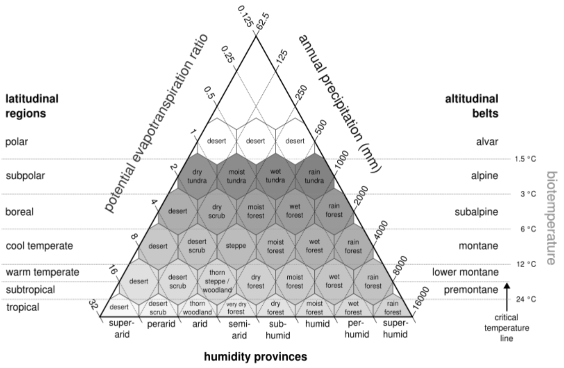

Figure 1: Holdridge Life Zones diagram.

Each zone corresponds to particular climatic characteristics and thus to defined vegetation types. The system determines thirty-eight different classes such as « polar desert », « warm temperate dry forest », « subtropical dry forest », « tropical desert scrub », etc. For example, in the subtropical category, the "dry Martini forest" is characterized in the following factors :

- biotempérature 12-24° C;
- potential evaporation ratio : 1-2;
- humidity: subhumid;
- average total annual precipitation : 50-100 cm.

2.4. Mahoney tables

The MAHONEY tables [3] characterise climates and with the aim of proposing recommendations for construction. These recommendations (seventeen) are divided into eight categories.

For example, in the tropical monsoon climate (table 2):

Table 2: Monsoon climate recommendations according to C. Mahoney.

category	Type
1-plan	orientation longitudinal axis E-O
2-spacing	wide spacing + wind portection
3-air	intermittent circulation of air
4-openings	/
5-walls	Heavy walls
6-roofs	Heavy roofs
7-sleep	Sleep outdoors
8-rain	Rain protection

The climatic data considered are:

- Temperatures (average, minimum and maximum).
- Humidity, precipitations and wind.
- Comparison of comfort limits.

These data make it possible to characterize climates and thus to propose guidelines for an adapted construction.

2.5. Givoni bioclimatic chart

A method suggested by GIVONI [4] as early as 1963 defines the main roads of construction according to the comfort zones. The method support is the psycometric diagram (refer to fig. 2) which represents the human comfort zone based on temperatures and air humidity. The method indicates, based on climatic conditions, where the confort zones are located and thus shows the axes of construction to be followed.

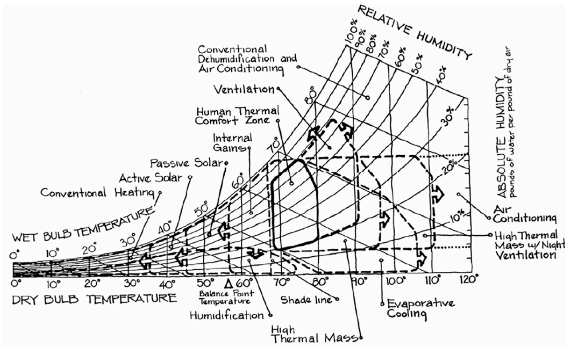

Figure 2 : Bioclimatic Chart [5]

2.6. Conclusion

Classification methods make it possible to characterise climates and their associated typologies of vegetations, constructions, etc. For classifications more related to construction purposes (Mahoney, Givoni), at least two problems can be foreseen.

Firstly, climatic typologies are primarily guided by a dominating objective: the hygrothermic comfort. Although important, this objective should not be the only one.

In architecture, other considerations can be influenced by the climate, such as visual comfort (quantity of day light, dazzling…), or water management.

Secondly, the climatic data considered are often too detailed, which is not necessarely relevant with the preliminary design phases.

We thus propose a method which tries to answer these questions.

3. METHOD

3.1. Climatic data

The starting point of our work is based on an approach first developed by Manon Kern [6] and used by the CRIT Architecture. This assessment approach of environmental quality of buildings was put forward based on a study of the existing certification methods (BREAM, LEED, HQE…).

The method was based on the evaluation of twenty-four targets, organized in phases, corresponding to the process of design and realisation (from preparation to occupation).

Each objective was evaluated by experts, ranking from 0 to 4, the average mark giving the project value. This evaluation was accompanied by a "radar" chart, as a help in comparing projects.

Applied on several occasions for buildings evaluation, this first version of the method was then criticised, in view of the criteria considered in the objectives evaluation and the need to determine more efficiently the context of each project.

We thus proposed to refine targets by defining them more precisiely in various criteria (table 3) and in taking into account the characteristics of each operation by defining a "context coefficient" (CC).

Table 3: Hierarchical method segmentation.

Target 1	
Criterion 1.1	CC
Criterion 1.2	CC
Criterion 1.3	CC
Target 2	
Criterion 2.1	CC
Criterion 2.2	CC
Criterion 2.3	CC
...	...

The aim of our work is to adapt the environmental evaluation according to the context of each project. The context is defined by the nature of the construction (new, rehabilitation…), the type of program (multifamily appartments, single house…), geographico-urban data (built-up area, isolated…) and climatic considerations.

From now on, we will limit ourselves to presenting the climatic data of contextualisation.

Initially, we tried to define standard climates associated with a specific weighting (refer to fig. 3).

Figure 3 : 1st phase of reflection

The characterization of elements in limited numbers raises the question of their. Defining a limited number of elements makes it possible to have a simple model, but it integrates only a small number of cases. On the contrary, determining a large number of elements makes it possible to consider more cases, but makes the model complex.

Making only five climate types (dry heat, wet heat, moderate hot, moderate cold, polar) does not allow us to propose a relevant model for a large number of situations. For example, in such a model the monsoon climate type, which has a hot wet period as well as a hot dry period, would not be represented in such a model. It however induces constructive singular characteristics which are neither those of a hot and wet climate, nor those of a hot and dry one.

To have a model adapted to all design cases, it would be necessary to characterize the whole array of possible climatic situations, which would make the model complex.

In a second phase, we reversed our reasoning (refer to fig. 4), looking at which climatic data influence the importance of the evaluation criteria.

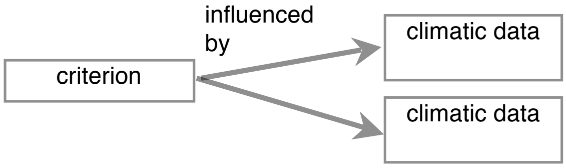

Figure 4: 2nd phase of reflection.

This makes it possible to restrict the data input to the only useful elements for the criteria definition, while preserving the effectiveness of the model. All climates can be considered as well as microclimates. Indeed, the method takes into account the climatic data from a given point and not an average of a region.

The climatic data generally considered to influence the environmental quality of a building are:

- temperatures (variations, averages);
- pluviometry (rain, snow);
- winds (speed and direction);
- sunshine (hour, radiation, nebulosity);
- humidity;
- localization (latitude, longitude, altitude, solar trajectory).

Our method objectives being to bring help in the early phase of design, all data available and useful at this moment in the design process must be defined. It is thus not necessary, in the early phases, to obtaine detailed climatic data. The latter will be crucial only at the end of the process, to optimize dimensioning of the architectural elements. On the other hand, it is essential to have a notion of the climatic conditions in which the project will take place.

It is also possible to estimate certain information by deducing it from other data. According to the temperature and pluviometry, it is for example possible to deduce the relative humidity and the potentiality of snow cover.

We thus propose to retain as essential data at the preliminary phases of design:

- Notion of low and high temperatures (Tb and Th). Value: high, very high, etc
- Notion of the amount of pluviometry (P). Value: important, very weak, etc
- Notion of winds (V): intensity, direction.
- localization, latitude (L); pole, tropic, equator.

In our method, we have thus indicated, for each evaluation criterion, a selection of climatic data influencing the design.

3.2. Assumptions

To determine these influences and to establish the context coefficients, we studied vernacular architecture and recent sustainable architecture. Indeed, the study of these architectures has allowed us to observe the design characteristics specific to each climate (refer to fig. 5).

For example, light architecture, and large roofs are typical of the architecture of a hot and humid climate. In contrast, in a hot dry climate we find the following features: a heavy compact design and a flat roof. The architecture in climates having both a hot dry period and a hot wet period has the characteristics of both climates.

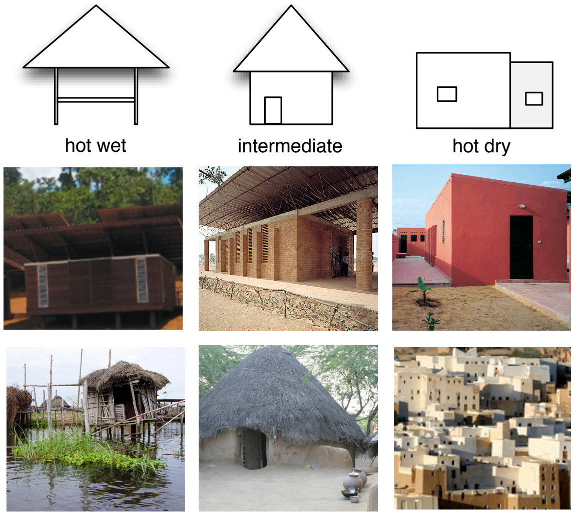

Figure 5 : architectural typology. Above: secondary school, J.A.G. (Papaïchton, Guyana), Primary school, Diébédo Francis Kéré (Gando, Burkina Faso), Womens's community centre, Saija Hollmén, Jenni Reuster, Helena Sandman (Rufisque, Sénagal). Below, vernacular architecture: Benin lake village [7], Bhil village, India [8]; Yemen [9].

So we have for each climate a particular type of architecture, and therefore unique needs. These needs can be analyzed through the study of these types.

In the example of a hot humid climate, the chareteritic of a large roof indicates the need for protection from the rain and sun, whereas the characteristic of light architecture indicates the need for continuous circulation of air.

These needs correspond to the different assessment criteria established. We were therefore able to identify which climatic data influence criteria (refer to fig. 6).

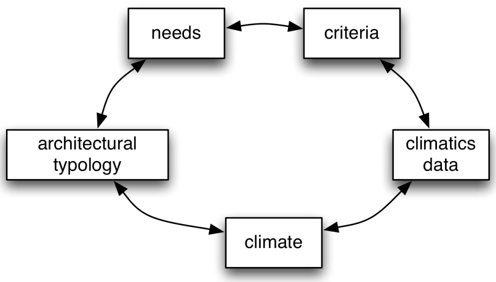

Figure 6 : relationship between architectural typology, needs , criteria an climatic data.

After having identifie which climatic data influenced each criterion, we formulated a first hypothesis about the criteria weighting system taking into account the climatic data.

Five class levels were proposed :

- / not important
- \+ slightly important
- ++ fairly important
- +++ important
- ++++ very important

The summary of the proposals is presented in a table which indicates the importance of the criteria according to the associated climatic conditions (table 4).

Table 4 : importance of the criterion

criterion	To collect, manage the solar contributions	Direct radiation protection	Optimized orientation of sunlight
++++	tb very low	Th average to very high	L tropic
+++	Tb low or L : pole	-	L pole and equator
++	Tb average	th low	-
+	tb high	-	-
-	Tb very high	th very low	-

4. VALIDATION

To validate our proposals, we carried out a survey involving building professionals. These were primarily European architects, but we also included designers involved in more contrasted climatic areas. The validation corpus thus included about fifty projects covering a dozen different climatic contexts (Australia, South Africa, Brazil, India, the USA, Canada…).

The survey was carried out using a questionnaire aiming to measure the relative weight of evaluation criteria in the design process, according to the contrasted climatic context.

Designers were required to answer based one the positions taken in particular projects, not on their general opinion.

Each designer was thus requested to indicate the climatic context of the project and to indicate the importance of each criterion in the project (table 5). Their appreciation was accompanied by a comment in order to give more precision.

Table 5: example of returned questionnaire, Catsieau Architect in Guyana, project for old people's home.

criterion	influence	comments
Optimized, orientation of sunlight	/	Without object; Existing buildings and quasi vertical sun
To limit direct light and dazzling.	/	Without Object; Sun very quickly at the zenith

To manage infiltration and water run-off on the plots.	++++	pluviometry very strong
Protection from strong precipitations. (External Spaces)	+++	Conform to way of life under open shelter

These questionnaires enabled us to appreciate the weight of each criterion in well-defined climatic contexts and thus to refine and validate the preliminary assumptions.

5. RESULTS AND DISCUSSIONS

Results must be relativized, based on the fact that the remote survey did not allow exchanges and direct dialogs, and therefore does not guarantee an exact comprehension of the question elements. Indeed, we have noticed that certain criteria were not understood correctly. However the comments allowed us to correct some comprehension problems and to draw a certain number of conclusions.

Firstly, the results of the various investigations clearly confirm the need to contextualize the criteria, according to the specific situations of each project. We noted that the importance of the evaluation criteria fluctuates effectively according to the climatic context of the operation.

Secondly, we refined our original weighting proposals. Some were validated, but others had to be modified.

For example, a starting hypothesis that "in a dry climate, there is no need to infiltrate and control water" was confirmed. This confirmation was based, for example, on an answer given to our survey, from a school project in Zanskar (northern India), directed by the architect Jan Tilinger (refer to fig. 7), where the pluviometry is relatively low.

Figure 7 :Bioclimatic school, Jan Tilinger (Kargyark, India).

On the other hand, the hypothesis that "it is very important to collect solar radiation in any cold climate" was revised based on the answers from different projects in Sweden and Norway directed respectively by the agencies S-XL architects and Snohetta (refer to fig. 8). Indeed in the cold climate at the poles, the sun is not very present, even absent, at the coldest periods. This criterion although important is thus not the first to be considered in such situations. It is more important to be isolated and protected from the cold.

Figure 8: national opera, Snohetta (Oslo, Norway)

Thirdly, whereas certain criteria did not appear to us to depend on climate, they appeared sometimes to be related to it. For example, the criterion "external extensions (loggia, balcony, terrace…) " which could appears as not very dependent upon the climatic context is on the contrary very related to it. Our survey revealed that in hot climates these elements were part of the life philosophy and thus were very important (refer to fig. 9); whereas in a cold climate this criterion is not prevalent, and even useless.

Figure 9: R.R House, Andrade & Morretin (Sao paulo, Brasil)

Finally, we clearly identified, thanks to the designers' comments, the key climatic data influencing evaluation criteria (table 5). This allowed us to refine our method.

Table 5: example of climatic data influencing the criteria

criteria	influence
Collect, manage solar contributions	- temperature (low) - latitude
Temporize heat	- temperature (high) - pluviometry
Collect rain water	- pluviometry
Optimize orientation of sunlight	- latitude
Orientation compared to wind	- wind
External extensions	- temperature

6. CONCLUSION

In order to progress, the evaluation of environmental quality must be defined. This is an actual recognized need. However, quality cannot be defined abstractedly. The concept of context, although complex and subject to interpretation, must be an integral part of the evaluation methods.

During this work, centered on the concept of climatic context, we identified the data required to adapt construction to climate at the preliminary design phases. We also defined the relative weight of each evaluation criterion to judge the quality of a project based on its context.

The results of this study will be used to develop an evaluation tool, allowing the designers to propose projects offering better environmental answers.

Complementary work in progress bearing on the concept of construction type or program should enable us to futher refine the projects' contextualisation criteria as well as the weighting system in our evaluation method.

7. ACKNOWLEDGEMENTS

We thank the unit architects who answered the survey and thus allowed the realisation of this research task.

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