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The multicriteria approach in the architecture conception: Defining windows for an office building in Rio de Janeiro

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ABSTRACT

The aim of this paper is to apply a multicriteria method to define windows for an office building conceived for Rio de Janeiro, Brazil, under a compromise between landscape view, daylight level on work plan and energy efficiency. The intent is to select one from six proposed window solutions differing in window size, type of glass and solar shading devices. Several methods are applied to assess the performances for each of these criteria. Simulations are performed to obtain the annual indoor daylight levels. The measurement of the sight angles is carried out to quantify the landscape view. The prescriptive method from the Brazilian building thermal regulation is applied to assess the energy efficiency of each solution. The obtained results of the monocriterion analysis indicate several criteria conflict. In order to identify the compromise solution, the ELECTRE III method is adopted by means of the CELECTRE software. The results of the multicriteria analysis indicate that all solutions with solar shading have a more satisfactory overall performance than those with solar control glazing and without shading devices. Due to the large dimensions of the studied floor, large size windows with solar shading devices achieve better overall compromise results. It is concluded that the multicriteria approach is a very effective method to consistently analyze the solutions proposed for a problem and to assist designers to minimize the conflicts between criteria. It allows performing an integrated approach, enabling a more conscious, accurate and responsible decision making.

1. Introduction

Windows are envelope elements that play an important role in the building overall performance. They are responsible for regulating the indoor admittance of solar gains, daylight, wind, noise and pollutants, and can enable a visual integration with the exterior environment. Windows can also define the building formal aspect and impact the construction costs and the building life cycle.

The window design is a complex task due to the number of environmental and energy requirements considered when defining the frame type, the size, the location and the glazing type. In order to reconcile all design requirements, one may often face the following situation: the satisfaction of one requirement results in the dissatisfaction of others [1,2]. Rarely, it is possible to find a solution that satisfies all the involved criteria. Therefore, instead of searching for an ideal solution, one must pursue a compromise solution, which will minimize conflicts between the criteria and reach a whole formal coherence.

In event, it is difficult to identify a compromise solution in the design process due to the multiple criteria assumed. Generally, architects have difficulty listing possible conflicts between criteria and also quantifying its influence level on the building overall performance [2,3].

Recent investigations point out the multicriteria approach as an efficient way to overcome difficulties on decision problems [4,5]. This approach has been applied by other fields of knowledge such as economics, management and engineering, and in the last decades, it has been adopted in architecture to assist designers in the decision process involved in new buildings conception and refurbishment designs.

Most of the studies that apply the multicriteria approach in architecture [6–13] are focused on energy and environmental criteria, which reflects designers concern in conciliating so many conflicting criteria related to the building sustainability, as described by Wang et al. [5]. Some works apply multicriteria methods to aid the selection of bioclimatic strategies to improve the environmental comfort and the building energy efficiency [8]. There are also studies that apply this approach to identify a

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compromise solution for buildings envelopes, considering construction costs, environmental comfort, energy consumption and pollutant emissions [9,10,13]. The multicriteria analysis can also aid to reconcile budget constraints with the maximization of the number of credits for environmental building certifications, as demonstrated by Lacouture et al. [12]. This approach is also useful for the early design stage, when defining buildings shape to reduce energy consumption [6] or buildings arrangements to improve natural ventilation potential [7].

Some studies are focused on developing new methods or tools to apply the multicriteria approach [9,13], demonstrating them by means of architectural problems. Nevertheless, their applications do not suit architects skills, since it involves specific calculation knowledge such as genetic algorithms, neural network and fuzzy logic. On the other hand, Castro [2] presents a new tool based on the ELECTRE III method - the CELECTRE - that performs instantaneously all operations involved in the method, which enables architects to incorporate more easily the multicriteria approach into the design process.

This paper applies a multicriteria method to define a window solution for a new office building in Rio de Janeiro. The aim is to identify which of the compared window solutions best reconciles three of several criteria related to windows: landscape view, daylight level on work plan and energy efficiency.

One of the main contributions of this paper consists of presenting a case where a monocriterion analysis turns into a multicriteria analysis with the aim to evaluate more consistently the architectural solutions. It also presents an application of the software CELECTRE.

By incorporating this approach into the design process, we intend to emphasize its potential to assist the designers in the conception of a sustainable architecture.

2. The multicriteria approach

By means of a multicriteria approach, it is possible to analyze a problem from different points of view. In architecture, a multicriteria approach can be used to compare different solutions for a design problem considering simultaneously several constraint criteria, with the intent to identify a compromise solution.

There are several methods oriented to the application of a multicriteria approach, each one adequate to solve a sort of problem [4,5,14,15]. In common, these methods follow four basic steps.

1.*Alternatives' formulation*: definition of possible solutions for the problem by choosing some design parameters;
2.*Criteria selection and weighting*: definition of the criteria to assess the solutions and determination of their relative importance (weights);
3.*Monocriterion analysis*: solutions performance evaluation for each criterion; and
4.*Multicriteria analysis*: application of a multicriteria method to identify the best solution(s) for the problem.

The first three steps are the same for all methods and are essential procedures for a multicriteria method implementation [14].

When defining the solutions, one may consider some design constraints in order to compare only the feasible and efficient alternatives. The criteria selection and weighting may be carried out by all the actors involved in the design process (architects, engineers, constructors, estate developers) and also the ones whose life will be impacted by the building construction [2]. The complexity of a multicriteria analysis is proportional to the number of chosen criteria, especially if they present many conflicts among themselves. Also, different weights influence the multicriteria analysis results. Consequently, weighting should be done carefully to identify a suitable solution for the problem [5].

The monocriterion analysis may be carried out by means of several methods, including numerical simulation [7,8], interviews with specialists [16] and environmental and price database research [12,13]. Regardless of the subjective or objective nature of the criterion, the solution evaluation may provide a quantification of its performance to enable comparing them in the next step.

In order to accomplish the last step, one should elect a suitable method according to the problem specificities. Wang et al. [5] summarize the main methods, classifying them into three categories: elementary methods, methods in unique synthesizing criteria and outranking methods.

The elementary methods are applied to simplify complex problems for the selection of a preferred alternative. They do not necessarily consider the criteria weights and indicate a performance score for each solution. These methods are more suitable when considering few alternatives and criteria. Conjunctive, disjunctive, lexicographic, weighted additive are some methods that represent this category.

The methods in Unique Synthesizing criteria are more complex methods that apply optimization algorithms. It consists of ranking the solutions on a single scale according to their performance over a criterion at a time. After the monocriterion analysis, each solution scores are summed or averaged to obtain an overall score, which will be then compared to identify the compromise solution. Analytical Hierarchy process (AHP), TOPSIS, Multi-attribute value theory (MAVT) and Multi-attribute theory (MAUT) are some methods of this category.

The outranking methods propose the comparison of pairs of solutions over one criterion at a time in order to identify the preference of one alternative over another. The preference information is then aggregated across all criteria to obtain a solutions ranking. In the comparative analysis, an inferior performance on one criterion can be compensated by a superior performance on another. The ELECTRE family method and PROMETHEE are the most used outranking methods.

The present paper employs the ELECTRE III method [17]. It was chosen due to its capability of establishing a solution ranking under a weight ponder, and also due to the availability of the software CELECTRE [2,18] that allows performing instantaneously all operations involved in the method (comparison and distillation), which turns this last step resolution faster and easier for architects.

3. Materials and methods

The case study consists of a hypothetical 13 floors office building, conceived for the Rio de Janeiro city, Brazil ($-22°50'$ latitude, $-43°15'$ longitude). The main floor is about 19 m width, 55 m length and 2.60 m height (Fig. 1).

The windows are placed on the Southeast and Northwest facades, as well as along the perimeter of a central atrium, which divides the floor into two areas of about 22 m length each. The other facades are opaque and touch the lateral terrain boundaries.

The Southeast facade is turned to a beautiful landscape view composed by an ecological park – Flamengo Park – the Guanabara bay, the Sugar Loaf and, far-away, the Niterói city.

The Southeast and Northwest facades present two triangular vertical elements close to the windows edges. It will complement the shading action from the protection devices that will be proposed for the openings.

This building may be occupied annually from 8am to 6pm, except during lunch break (12am to 1pm) and weekends.