Cost Performance Based Design

Using Digital Technology for Cost Performance Simulation in the Conceptual Phase of Design

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This work studies the Performance-Based Design approach, focusing exclusively on cost performance, asking how to launch the architectural portion thinking of the cost of the building in a way that such performance can directly influence the project design and architectural form and how can shape, type and structure of the building influence the final cost of the work. For this, we chose to analyze the DProfiler software for the development of models in order to produce an architectural form that directly meets the performance cost requirements, following specified formal language, which aligns cost and project intention in the initial phase of the design. The research showed that the use of Macro BIM software platform is promising and that the generative design process can and should arise from an organization of the parts and not from predefining it as a whole, achieving an architectural project that is attainable and more sustainable.

Keywords: Performance Based-Design, Cost Performance, DProfiler

INTRODUCTION

Among the various approaches in the contemporary design process arising from computerization and digital technology, there is one that considers building performance as a driving force from the moment of formal conception. It is what we call Performance-Based Design, whether it be thermal, acoustic, environmental, luminal, structural or cost-based (KOLAREVIC, 2005). Using the performance-based design approach, architects can employ these tools not just to simulate what is already built, but also to create, generate, reshape and rethink their forms before they even complete their design. In such an approach, it seems that the established paradigm of conjecture and test is applied at the time of formal design, causing architects and designers to find supposedly optimized solutions (OXMAN, 2008b).

One example of performance shaping the initial form is the Rensselaer Concert Hall, in New York, designed by Grimshaw (see Figure 1a), where form was thought to attain the acoustic performance, similar to like the manufacture of a Stradivarius violin. This also happens in the Sarah Kubitschek network of hospitals, in Brazil (see Figure 1b), conceived by
João Filgueiras Lima, where the roof is designed like big shafts that allow for internal ventilation as well as improved temperature conditions throughout the building. Now in the case of London City Hall, designed by Norman Foster (see Figure 1c), the previous structure was transformed to achieve acoustic performance, avoiding echoes in the entrance hall.

In this kind of approach, Oxman (2008b) says that architects have a new role and they can find supposed optimized solutions. But how do architects find their architectural solutions? According to Logan (1987), Asimov (1962) saw the project as a process in which the problematic situation should be resolved through decisions made and subsequently tested and evaluated; Markus (1971) brings the project activity as a sequence of decisions that will be analyzed, synthesized and evaluated; Broadbent (1973) includes a feedback loop in the process, meaning that at any time additional information can be included in the sequence of decisions; Lawson (2005) in turn states that the project activity goes from general to detailed, following standards of analysis and synthesis. Although these four views on architectural design have different approaches, the planning thought process paradigm seems to be the same: analysis, synthesis and evaluation. So we establish the thought of design as being based on past studies by such researchers and generalize this thought process, characterizing its paradigm as "conjecture and test".

However, while the performative approach puts forth a change in the design process and redefines the role of the architect, one may question whether it has modified the established paradigm. To what extent is this well-established idea of "conjecture and test", in fact, being challenged by performative architecture? Hence, our work aims to answer this question, trying to conceive architectural forms that directly meet cost/performance requirements, following certain formal language, combining costs and design intention in the early planning phase. When we talk about formal language, we use the definition proposed by Mitchell (2008) in "The logical architecture", where he compares architectural language to grammatical combinations in language and following previously established rules, which determine how the parts can be manipulated in a design-based universe.

**METHOD**

Because architecture might be a compromise among function, material, form, quality and cost, and its construction always implies an effort that has to be worthwhile, the economic aspect of the building has been considered a main topic since the beginning of architectural theory. Thus, we consider that the architect should be a bridge between the creative and the achievable.

To achieve this, the "Digital Technology for Cost Analysis" was applied during the conceptual phase. Using DProfiler software 1.1, a budgeting tool developed by Beck Technology, it was determined that we would model, modify and analyze four building models with specific budget constraints in accordance with the following criteria: the quantity and speed of the steps involved, the level of automation and optimization and the compliance or non-compliance with the "conjecture and test" paradigm, as well as
cost variation during the design process.

Although we know that every project has several factors to be taken into consideration, including customers, programs, standards, climate, site, technology, sustainability and costs, the criteria included in this research are: program, sunlight and ventilation, form (in this case, we noticed certain limitations in the software when working with less orthogonal shapes, since the structure is given only orthogonally) and specific budget. Even though the software provides the building adequacy in soil study methods and earth moving costs, we set aside this criterion, since our focus is the shape of the building.

But before detailing our results, some definitions must be determined: 1. Conceptual phase: when the designer begins to envisage forms and possible solutions. 2. Automated: The computer provides the result after inputting specific information. 3. Semi-automated: the user needs to utilize other software or method to obtain the final result. In this case, the computer provides partial results. 4. Digital Process: carried out using entirely computational means.

5. Number of evaluations: the moment in which the user must stop the creative and speculative process to check results. 6. Macro BIM: a tool that works with more generic information and parameters, with the possibility of working with additional volumes and information. 7. Micro BIM: a modeling tool that works with more specific information and parameters; in this case, the modeling of all construction elements is required (see Figure 2).

Despite the fact that the financial field values are given between minimum, maximum and average, the values discussed here are the average values of cost, based on specific tables provided by CAIXA (Brazil Federal Savings Bank), an institution that researches the cost of construction in Brazil, as it is an active lender in this segment. We do not seek to find an international average, due to the gap in construction technology, materials used and the economic conditions of each country.

RESULTS

1. Our first test sought to illustrate how the arrangement of environments in a single project, such as a residence, could change the final figures of the construction, considering foundation, structure and sealing. We considered the perspective of how the layout of a house can be more economic in terms of cost. Unlike algorithmic software, where the configuration of environments is given through information previously provided, in DProfiler, in the case of this residence, the arrangement was given by the author. The software creates nothing and only calculates the cost of specific changes.

The software’s response was consistent, as it instantly showed how the changes in floor plans affected the building costs. The first model was the most economical in terms of cost, in which each square meter totalled R$ 173.30, while in the third model the cost of each square meter was R$ 207.38 (an increase of 19.67%), as a result of modifying the layout of the rooms (see Figure 3 and 4). Both the outer structure and the inner organization of the building were considered. This analysis showed that the designer can secure a preliminary answer as to which is the most economical form for the residence.
2. The second test was performed on a five-floor building model (see Figure 5a), with an initial construction cost, given by the software, of R$104,283.00, including foundation, structure and masonry.

The floor plan positions were modified so that the pillars and cantilevered slabs were not plumb (see Figure 5b). Upon analysis, it was noted that the slabs were not extended because the volume did not intersect with the horizontal structural mesh (see Figure 5c). By using the "move" editing tool, the lower horizontal planes were pulled down, so that the software extended the slab (see Figure 5d). In doing so, the software showed a 33% increase in building costs (R$136,650.00).

3. In the third study, we used the same previous model (see Figure 6a) and modified from subtraction, addition, increase and decrease volumes in order to double the cost of the building, in which the initial expenses were R$104,283.00 and the limit would be R$208,566.00.

The software screen sharing option enabled instant verification of the results that were obtained with each modification. The whole process of solid modification lasted 17 minutes and was recorded in the chart below (see Figure 6c), which shows the range of values in accordance with the changes in the building form and configuration, showing the author's attempt to reach a satisfactory cost performance, a constraint defined before any formal speculation. The Figure 6b shows the building after the implementation of filler material in the facade, where the color brown represents the sealing.

In an attempt to use the results of this study as a model for other software such as AutoCAD and Google SketchUp, we were able to obtain some answers and, with regards to interoperability between these programs and the DProfiler, the following observations were made: 1. The option of exporting the solid developed in DProfiler is only possible for AutoCAD (DWG) and only the slabs are exported (see Figure 7a). 2. The proportion remains, but the scale does not. 3. For volume development in SketchUp 7, it must be imported from AutoCAD. From the slabs, the volume scale must be modified.

4. After modifying the scale, the construction of the slabs is necessary because only the measurements of these are imported. After that, the walls should be constructed, which will result in the building (see Figure 7b). 5. After the development of the volumetry, the ground, textures, shadows and components can be added to the volume (see Figure 7c).

4. The forth test altered the previous shape in order to generate intersecting and cantilevered spaces, by way of surface subtraction, addition, increase and decrease with a budget constraint of R$273,300.00 (double the final cost of Model 2). In this case, an increase in glass windows was taken into consideration, with their placement correlating to the position of the sun (see Figure 8).

This process took 72 minutes and was composed of 149 steps to obtain the defined cost performance. Looking at the chart (see Figure 9), we note that the first 60 steps were more speculative, pertaining to changes made to the form.

From step 60 to step 143, from a level of formal satisfaction, all the frames were located, in an effort to guarantee satisfactory results concerning sunshine
CONCLUSION

In this research, we were able to verify that the software has been successfully used for building design following specific criteria, achieving good results with respect to cost performance. Considering these results, the following considerations can be made: this experiment was characterized by a digital process of partially automated decision sequences; the developed models had rapid, formal results and a small number of assessments; automation in relation to obtaining financial results was complete, at which time the changes were not automatic but, rather, speculative, due to the external actions of the architect; even though random changes were made to the shape, they were made in order to achieve a specific performance using a process that is no longer more speculative when approaching completion, so, in a way, it contradicts the "conjecture and test" paradigm.

This paradigm, which we believe to be consolidated, results in the architectural concept rarely following the budget data of the future building. That is, the process appears to begin with the whole project to then consider its individual parts (Top / Down - see Figure 10). However, beginning with models 3 and 4, the research reversed this process, as it was necessary to provide the software with all necessary information regarding costs, parameterization and construction items. Thus, a method was created to begin with the parts and create the whole (Bottom / Up - see Figure 11). In this approach, the final construction cost and the program are interrelated and influence the whole design process. The result should correspond to the previously defined cost of the desired project before any formal and programmatic speculation.

In the case of the last two studies, although we have begun based on the principle of following the cost performance, it is still necessary to address the fulfillment of this form in relation to other criteria including esthetics, suitability to the needs program, type of soil and structure, final load of the building, ventilation, lighting, etc. Since the project deals with appearance, it is influenced by the author. But in a performance-based project, the proportion of authorship is lower when compared to a conventional design.
We are not trying to simplify a process that we know to be complex. This initial phase is characterized by a high level of abstraction, with great ambiguity and uncertainty. However, one can notice a path that goes from the abstract to the concrete, from the changes in the form; that is, we can work with models so that they do not exceed the previously established budget limits.

In addition to demonstrating a reduction in the use of various software for budgeting and formal design, which would require greater time, this paper has shown that the use of MacroBIM platform software for the development of architectural solutions is promising, and that design practices based on the performative model can be implemented within the current technological stage. Moreover, the software makes it possible to obtain a large number of solutions from a small amount of information. Therefore, a single architect, in a short period of time, could develop a diversified range of architectural solutions and, accordingly, choose the form that best fits the budget constraints, putting the architect in the position not only of creator and organizer, but also of construction facilitator.

FUTURE WORKS

The challenges in the use of DProfiler tools include:
1. The combination of this tool with other performance analysis software (climate, sound, structural, etc.), and the participation of industries and businesses in the research process of answers offered for their tools;
2. Further analysis of this work, with the inclusion of other building elements, such as coating, painting, covering, facilities, etc. This type of research can be expanded in the future to even more abstract issues, such as aesthetic and social ones, helping avoid, in the future, that buildings be designed in isolation, disregarding certain performance criteria or being modified after execution to solve problems that were not considered during the design process.

REFERENCES

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