The use of simulation to evaluate design options on conceptual mass study phase

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ABSTRACT
This paper presents the results of an exploratory study developed with the Autodesk Project Vasari and AutoCAD Civil 3D. Project Vasari was used to evaluate the environmental performance of a low-income housing project. It shows us that the actual site orientation of the project presents poor environmental performance, which could be improved by rotating building in 90 degrees. The AutoCAD Civil 3D was used to evaluate how that rotation should impact on earthmoving. The results showed that the simulations developed, even though having low level of accuracy, provide sufficiently clear information to support decision making on conceptual mass project stage.

KEYWORDS: Simulation tools, Performance-based Design, conceptual mass studies.

Introduction

Evaluation of building performance is a complex task that involves a large number of interdependent variables and multidisciplinary concepts. The advent of computers and digital simulation tools has been fundamental to the development of digital models that represent buildings behavior, allowing different scenarios simulation (Mendes et al, 2005). The new developments on simulation tools include the use of its outputs to design evolution and decision making (Augenbroe and Hensen, 2004). Nevertheless, it is important to have accurate and accessible simulation tools, and that it can be applied to simplified models. This allows the performance simulation be applied in earlier stages of design process. Having this need as motivation, this study aims to apply two simulation tools to perform simulations in conceptual mass studies. We are looking for identifying how it can be integrated into the design process in order to support decision making and the design evolution.

We used Project Vasari to evaluate the environmental performance, such as natural ventilation and solar radiation, of a low-income housing project located at the City of Campinas (SP/Brazil). Then, we perform simulations within AutoCAD Civil 3D to compare leveling quotas and determine the influence of earthmoving in two different design options.

Simulation and decision support in the design process

The search for an efficient built environment initiates at the design phase and performance simulation are important architectural design tools in such context. The fundamental works on performance simulation algorithms were developed a few decades ago. However, tools continue evolving and advancements in building simulation environments have focused on the framework aggregating algorithms, data management, interfaces (user and application) and activities they support. To increase the use of simulation in design, decision support environments, interoperability, user-friendly interfaces and visualization techniques are being developed and incorporated. It is possible to build a complete and accurate virtual model and perform multiple simulations.

The design environment of the architect is characterized by multiple computational tools, which are useful at different stages of the design process. Therefore, there is the need to move the digital model quickly between different software packages and to incorporate transformations from untyped holistic models to detailed typed models. New developments on Building Information Modeling (BIM) aim for integrating analysis and modeling tools in different design stages. To achieve such integration, tools have to be adapted for each design phase. Moreover, they must be highly visual and interactive, allow easy import and export, and provide feedback on different levels of details.

In the design process the building model may be subjected to different simulations involving different software. To do this, the model should contain all necessary information for all the different evaluations. Thus, performance simulation tools are mostly used at the final stages of the design process, to evaluate the building systems, when most of the decisions have already been made. However, this has been changing. The new paradigm for the simulations tools shift from tool integration to process collaboration. That is, the simulation acting as an element in the design process management (Augenbroe and Hensen, 2004). In this context, the simulation must be used since the beginning of the design process to improve communication between professionals of different disciplines and to provide information to support the decision making. Augenbroe and Hensen (2004) point out that the support for rapid evaluation of alternative designs, better adaptation of simulation tools to decision making processes, and team support of incremental design strategies are the main features to be better achieved by the simulation tools. It means that simulation must shift from only analysis to analysis and design aid (Malkawi, 2004). It can be done with the insertion of its results in algorithms for form generation and design optimization.

As an example, Malkawi et al (2005) developed a decision support mechanism based on a genetic algorithm to form generation and on Computational Fluid Dynamics to thermal and ventilation evaluation. In this mechanism there is also a visualization module that allows users to select the shape of the design instances as they evolve. The mechanism explores design solutions based on a set of performance requirements in order to achieve optimization, to facilitate the decision making process and to improve creativity. In this case, the process is not totally automated. The designer can intervene in the process to have control over the selection and evaluation activities.

In another study, Reichard and Papamichael (2005) merged two software applications, a code compliance and a multi-performance simulation tools, to improve decision making in the earlier phase of the design process. The final software offers rating parameters that aid the decision makers to select between different design solutions.

Despite the benefits coming from the simulation technique, through it is not possible to predict the future, but with some confidence, it is possible to predict the behavior of a system based on input data and observing a specific set of assumptions. Thus, simulation works for scenario analysis, not being able to identify an optimal solution by itself.

Methodology

A design exercise was developed in order to evaluate the use of Autodesk Project Vasari and AutoCAD Civil 3D in early conceptual analysis. We analyzed thermal performances and the impact of the building deployment on earthmoving. These performances are very important for sustainable development in tropical countries.

The design exercise was developed as a case study on a low-income housing project. The Campinas F housing development, located in the City of Campinas (SP/Brazil), was the project selected for the study. It is very characteristic of low income housing projects implemented throughout the country. The project current condition was modeled and evaluated within VASARI and AutoCAD Civil 3D. The simulation results were analyzed and a new design option was proposed.

Design exercise

The study began with the inclusion of site data and importing the building model to the VASARI environment. However, importing other software generated model resulted in significant losses of information. Due to this, it was decided to start modeling in VASARI in order to achieve data integrity to enable the later stages.

Thus, the conceptual mass model of the building current state was developed. Then, the ventilation and solar radiation simulations were performed. The results showed a poor performance to both simulations. The current state of ventilation performance reveals a low air velocity trough the buildings. For the solar radiation, we observed high solar radiation intensity on the longitudinal facades and on the roof. From the results obtained, we proposed new building orientation options with the help of the "Design Options" resource. The buildings were rotated 90 degrees. The new deployments were subjected to further evaluations, whose results were compared to the current state. The evaluation results were presented in the form of color scales on the object. This allowed a quick and clear comparison of the solutions. Figure 1 shows the simulations results for the current state project.

For natural ventilation, blue means lower air velocity, yellow means higher air velocity. For solar radiation, blue means lower radiation intensity, yellow means higher radiation intensity. It was possible to conclude that for

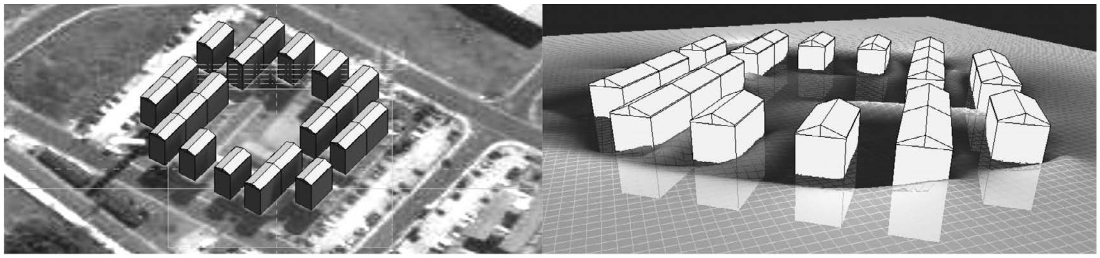


Fig. 1. – Current state project results

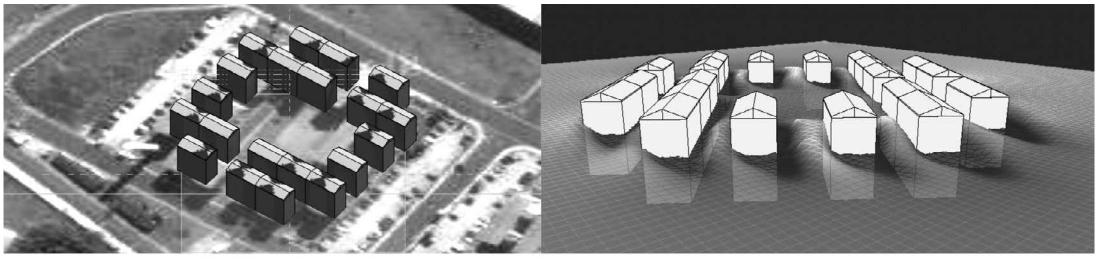


Fig. 2. – Proposed state project results

environmental parameters the actual site orientation of the studied housing project presents poor performance. The results could have been improved back in design by simply rotating building orientations.

On proposed project, buildings were rotated 90 degrees. It presented a better result for both evaluations. The ventilation simulations reveal improvement in cross ventilation, noted by higher air velocity through the buildings. Solar radiation simulations reveal a reduction on the radiation intensity of the longitudinal façades and even of the roof (noted by blue spots). Figure 2 shows the simulations results for the proposed state project.

The proposed building deployment led to changes on site topography. New leveling quotas and building pads was proposed and evaluated within AutoCAD Civil 3D. Each new proposed design and the current condition were compared with the natural landform of the site. To evaluate the impact of the site grading, we subtract the two models (natural – designed landform). Figure 03 present an elevation map resulted from this subtraction. From this operation, the program calculates the volumes of cut and fill land.

It is important to evaluate the total amount of grading, but also the difference between cut and fill land. If the volume of removed soil is bigger than the deposited, it indicates waste of soil. The contrary indicates that soil from another site must be removed. Both situations must be avoided.

Table 1 indicates the values of cut and fill volumes and the difference between then for each situation evaluated. First we evaluated the project current state. Then, we evaluated a first design proposal (design option 1). This first option was proposed in order to better accommodate the rotated buildings. After that, we made changes on site design to improve the results (design option 2). The subtraction result of the second design option is presented in Figure 04.

Thus, at the second option, the cut volume and the difference between cut and fill decreased.

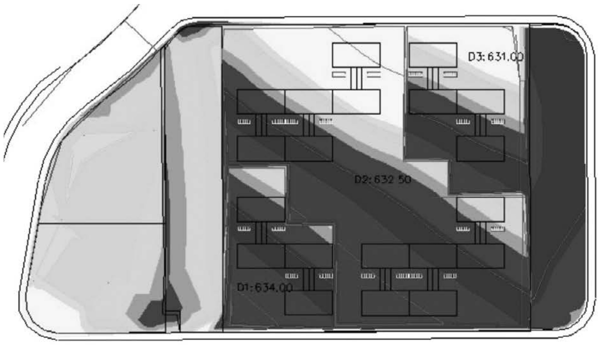
	Cut (m3)	Fill (m3)	Difference Cut-Fill (m3)
Current State	8196.18	589.00	7607.18
Design Option 1	8627.44	709.20	7918.24
Design Option 2	8595.47	761.73	7833.74

Table 1 – Grading performance results

The results show us that the current condition has a better grading performance although the poor environmental performance. On the other hand the design options have better environment performance, but led to much earthmoving. The choice between than depends on the level of importance of each variable for the decision maker.

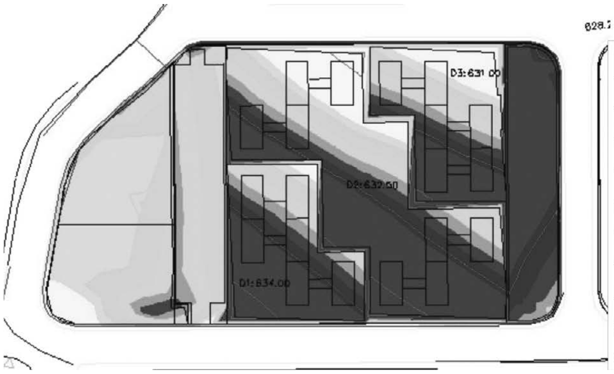
Results

VASARI performs energy, solar radiation and air flow simulations. It demonstrated to be an efficient tool for early design studies and conceptual modeling in the context of performance-based design. As potentialities, the program brings evaluation functionalities to initial phases of design, when information is still not much detailed, and allows the use of simulation results to support decision making. As limitations, it was observed low interoperability with other tools, even being of the same developer. Moreover, the mass modeling is not user-friendly. Even simple geometries require a lot of practice, which does not favor the flexibility to develop conceptual models alternatives.



Elevations Table			
Number	Minimum Elevation	Maximum Elevation	Color
1	-2.836	-1.382	
2	-1.382	-0.944	
3	-0.944	-0.570	
4	-0.570	-0.397	
5	-0.397	-0.163	
6	-0.163	-0.003	
7	-0.003	0.138	
8	0.138	1.722	

Figure 03 – Elevation map for the current state subtraction



Elevations Table			
Number	Minimum Elevation	Maximum Elevation	Color
1	-2.478	-1.060	
2	-1.060	-0.844	
3	-0.844	-0.682	
4	-0.682	-0.506	
5	-0.506	-0.281	
6	-0.281	-0.007	
7	-0.007	0.176	
8	0.176	1.322	

Figure 04 – Elevation map for the proposed state subtraction

AutoCAD Civil 3D does not have building information modeling features. Thus, the outputs are results of geometric operations, without considering the object properties. However, at design initial stages these properties are not fully determined. In the presented case, the tool helps us to identify how we could improve the design and achieve better grading performance results. Fig. 3 – AutoCad Civil 3D simulation output

Both tools show the results qualitatively by means of color scales (Figure 3) that allow a rapid interpretation, or quantitatively by means of comparative reports, graphs and charts. The quantitative results can in turn serve as inputs for the variables of regulation of parameterized model. This helps to feed back into the recursive process of project analysis, synthesis and evaluation.

Conclusions

The design exercise showed us that simulation is an important resource to be used at the design process. It helps the designer to make decision based on more real information. Furthermore, the graphics generated by the simulation tools presented the results in a comprehensive manner, which provides better insights to propose design changes.

Both tools are applicable to initial design phases, but they need to incorporate BIM features. They must also improve interoperability to be applicable at more advanced phases.

It is important to note that simulation tools helps in decision making, however the choice of the better solution depends on the values of decision makers. By considering more performance dimensions, one needs to incorporate a multicriteria decision aid approach to support decision.

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