Using Building Performance Information in the Design of Floor-Plans

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ABSTRACT

This research focuses on a new workflow between Space Layout Planning (SLP) and Building Performance Simulation (BPS) fields for the early stages of building design aimed at reducing energy needs of a building and improving indoor environment quality. Parameters of environmental performance requirements such as temperature, view, acoustic, etc. from different international norms were selected. The purpose is to link these performance parameters to a graph file. This graph supports schematic design tasks during the creation of architectural floor-plans. Programming tests were run to add the information to the graph. A prototype for the early stages of the design is presented. In this prototype, designers can visualize performance information during schematic design of floor-plans of a building. A study case is presented to demonstrate the usability of the concept.

GOALS AND HYPOTESIS

The aim of this research is to link the comfort parameters and the space layout planning during the early stage of design through an innovation in BIM platform. The hypothesis is as follow: is it possible to visualize variables of performance parameters during the stage of Space Layout Planning within a BIM environment? This paper describes the first part of the research, and it deals with the visualization of such variables.

The first was to define the parameters to be considered. Several internationals norms and assessments schemes were reviewed (BREEAM-UK, LEED-USA, DGNB-Germany) and some common attributes to define performance parameters were extracted. From this analysis one can conclude that aspects such as Day-lighting, view, acoustic, etc. are considered to evaluate the quality of the space. Finally some Chilean norms are reviewed to acquire real data to be used in a case study.

All these variables must be considered in the early stages of the design. In this stage architects made schematic design and this is basically rectangles arrangements, each rectangle represents a required area or room. Architects move and resize these rectangles until they fulfill the most of design the constraints (aesthetic, client needs, construction regulations, etc.). After that, in the stage of design development, these rectangle shapes are drawn as walls, windows, doors. Then the final result is a floor-plan that contains precise sizes, functions and materials. In this paper rectangle shapes are considered for the Space Layout Planning process.

LITERATURE REVIEW

Graph Theory applications are considered for the Space Layout Planning process, since they have been widely inquired and tested in architecture (Earl and March, 1979; Wilson, 1999; Rahman et al., 2002) and several other disciplines. Graphs allow users to handle and visualize complex information and relationships.

The problem of Space Layout Planning and the variables of ambient performance are currently handled separately by architects. Architects imagine and group the rooms and the performance targets just in mental way of thinking. This traditional method is made in two dimensions and tends to avoid exploring all alternatives because of time restrictions; and also leads to a risk of omission of performance variables. In the other hand the most of the software for Building Performance Simulation (Ecotect, Green Building Studio, TAS, Design Builder, etc.) requires normally to redraw all three dimensional volumes for calculations (zone/spaces modeling). This means extra efforts in the early stages and leads to unlink the flow with the schematic design since it requires ready floor-plans.

In this paper a prototype that shows the variables (and their values) to architects during the design of a floor-plan is presented. Several graphs tests, graph editing and programming techniques are carried out to develop a new concept that links both worlds.

Of course the complete world of variables that affect the ambient performance in the Space Layout Planning stage is very complex. Nevertheless the current global concerning on this problem has motivated to governments, universities and industry to quickly identify and classify which are these variables and which of them have more impact, this allowed to elaborate several tables with values (European Committee for Standardization, 2002; Roderick et al., 2009). These tables are available normally in norms such as ASHRAE, CIBSE, IESNA, ISO7730; while the architect´s work for this stage is commonly developed in a digital environment such as traditional CAD software or recently using BIM software [Eastman et al., 2011; Bazjanac, 2008; Krygiel and Nies, 2008). In this Space Layout Planning stage architects draw shapes, usually rectangle shapes (as explained before) that represent spaces or areas from the Space Program of the client. Those spaces have specific sizes and complex functional relationships. Architects must fulfill successfully this stage from the architectural point of view (aesthetic, composition, functionality). However the variables of performance parameters not always fit with the geometrical solution of the floor-plan, for this reason the visualization of these variables during the creation of the floor-plan is a crucial task to ensure performance quality of the design.

DESCRIPTION OF THE VARIABLES

Variables have been divided in two groups; those who depends on the geometry of the building (daylight, lighting levels, solar penetration) and those who depend of materials and more accurate climate data (Zone temperatures, air change rate, reverb, etc.). For this example will be considered: Temperature (°C), Illumination (Lx), Acoustic (Db.), View/Glazed (% of the exterior room´s surface). This type of information is expected to be added to the graph model. Energy analysis, formulas or physic calculations are not part of this research. To prove our concept, a small group of values for these parameters was selected to be used in the prototype (Table 1).

Table 1 Sample of variables to be shown in the prototype (Own Elaboration, 2013)

Parameter	Unit	Sample 1 Corridor	Sample 2 Class-Room	Sample 3 Director Office
Temperature	°C	15°C-20°C	Min 12°C *	-
Illumination	Lx	150 (lux)	300 (lux)	500 (lux)
Acoustic (Minimum Air Noise	Db	45 dB	50dB	35 dB
View/Glazed	%	20%	20%	-

(*) Current chilean regulations for thermal comfort in school classrooms are very weak, as they define a minimum indoor temperature of 12°C

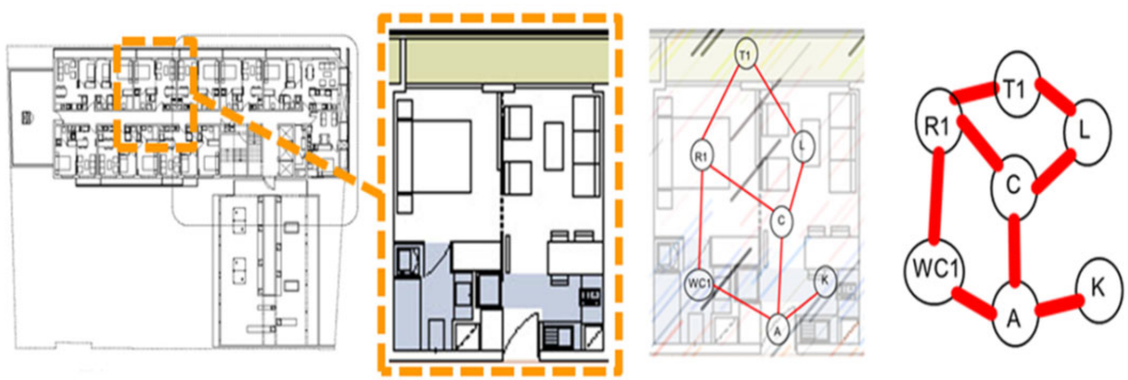


Figure 1. The Building, the Floor-plan, the Flat, and the Graph. Source: Lobos 2011.

EXPERIMENTS / CASE STUDY

Public Buildings have been chosen as a case study since they must fulfill a new Building Performance Regulation 2012 executed by the Chilean Ministry of Public Construction (Ministerio de Obras Públicas, 2012). In this new norm we can found exhaustive information about performance parameters and their target values that different types of spaces/rooms must fit in a Chilean public building.

According to (Lobos, 2011; Liggett, 2000; Medjdoub and Yannou, 2001; Earl and March, 1979; Rahman et al., 2002) graphs have been chosen to describe and visualize floor-plan information. Graphs can represent a schematic floor-plan (Figure 1, T: Terrace, R: Room, L: Living Room, C: Corridor, A: Access, K: Kitchen) and new design can be done. A case study (Figure 2) will be discussed in the next section. However, our hypothesis is: additional information about performance parameters can be added to such graphs and visualized to support the Space Layout Planning process. To prove this, an exhaustive inquiry about properties of graphs and the use of graph editors have been made. The experiments carried out on an existing graph prototype (Lobos, 2011) and they consisted in the exploration of possibilities of turning graphs into XML (Extensible Markup Language) language and editing its structure and codes by adding new information. These tests were made in Visual Studio programming environment and a XML Editor. Several codes lines containing the selected parameters were added to the structure and tested.

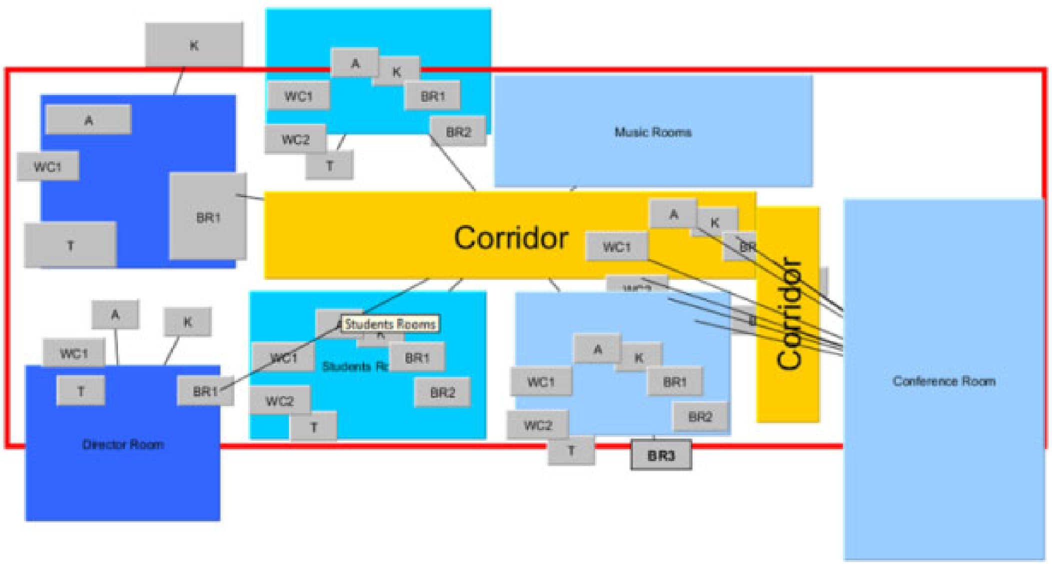
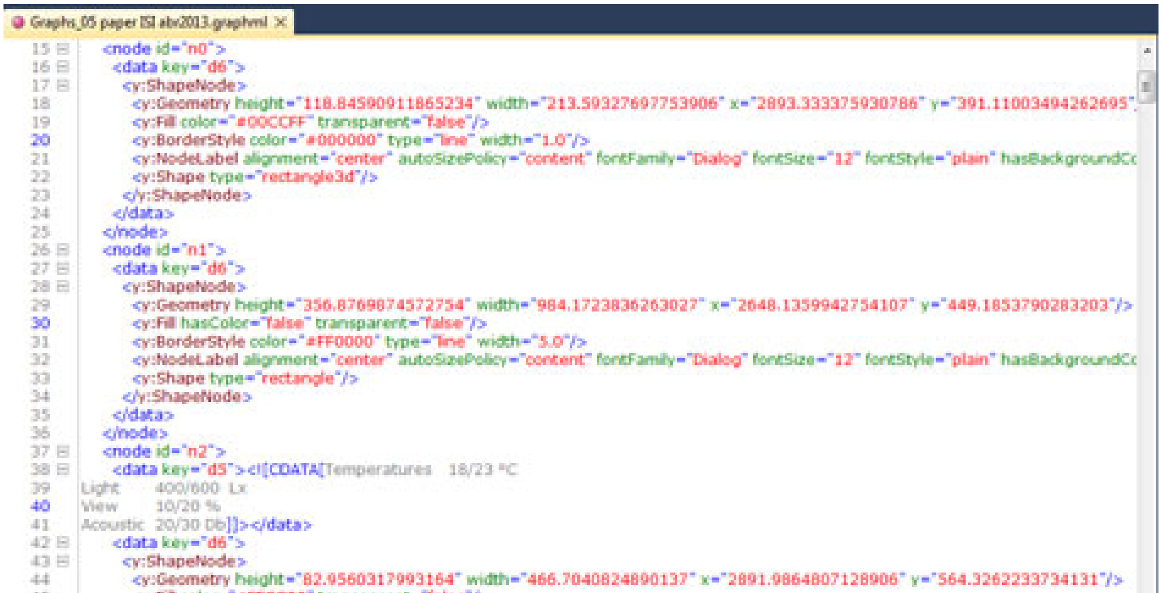


Figure 2. Graph file supporting the design of a new schematic floor-plan. Source: Own Elaboration.

After all tests it has been concluded that it is possible to edit the graph structure, to add external information and finally to visualize this information in a user friendly environment. The experience is as follows: several graph software and several XML editors were tested. After using and testing about fifteen graph software, satisfactory results were obtained. The test consisted on a set of actions such as open external graph files, importing spread-sheets tables, creation of simple graphs, graph geometry edition, and exporting graph using XML extension.

After these tests yED software was selected for the graph creation and after three tests related to XML editions, XML Blueprint 8 software was selected for the XML edition. By editing the XML structure it was possible to add some new code lines that contain information about the required values for each parameter about the Chilean norm. Figure 3 shows code lines 39 to 41 containing this information. The environment selected for the visualization was HTML since it can be accessed on-line. Microsoft Internet Explorer 11.0 was used for the test since its use is wide spread (BIM software such as Autodesk Revit will be used in the future)



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Graphs_05 paper ISI abr2013.graphml
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Light      400/600  Lx
View       10/20 %
Acoustic   20/30 Db]]></data>
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Figure 3. Edition of XML schema for a Graph. Source: Own Elaboration.

In this new interface the experience is as follows: the user approaches the mouse to any room, automatically a blinking message appears over the room and it shows the information about required performance for the selected room. When the mouse is removed from the room, the information disappears and information about other rooms can be inquired by only approaching the mouse without clicking the room. This allows architects to visualize specific information while they made decisions on Space Layout Planning.

The main advantage of this framework is that designers can decide crucial aspects of the project (orientation, size, room distribution) using real information from existing standards or norms in an integrated digital environment. These decisions are made in schematic early phase where design can be easily done and undone. Design options can be easily explored to find an optimum room performance.

A single case study for the early stages of design is presented, where the architect must design a simple layout for a small school in Santiago de Chile. He must fit the spatial program requirements (list of rooms: corridors, conference room, music room, director room, etc.). Once he opens the prototype, a graph can be easily obtained from the spatial program requirements, and then he can create the rectangle arrangements by respecting aesthetics and/or any other criteria (structural, costs, functionality). By moving and resizing the rooms, the prototype allows fast work and easy exploration of design alternatives: if architect changes the rooms, he can decide whether to fulfill the comfort parameters or to continue iterating the design. There is no need to put comfort data again into the prototype. Finally a schematic floor plan is created and it can be exported for the next stage called "Design Development" where detailed floor-plans are specified (walls, dimensions, material types, etc.) in any other CAD software. In Figure 4 comfort parameters for a corridor during design process can be seen, after designers iterative process the schematic floor-plan is ready (below).

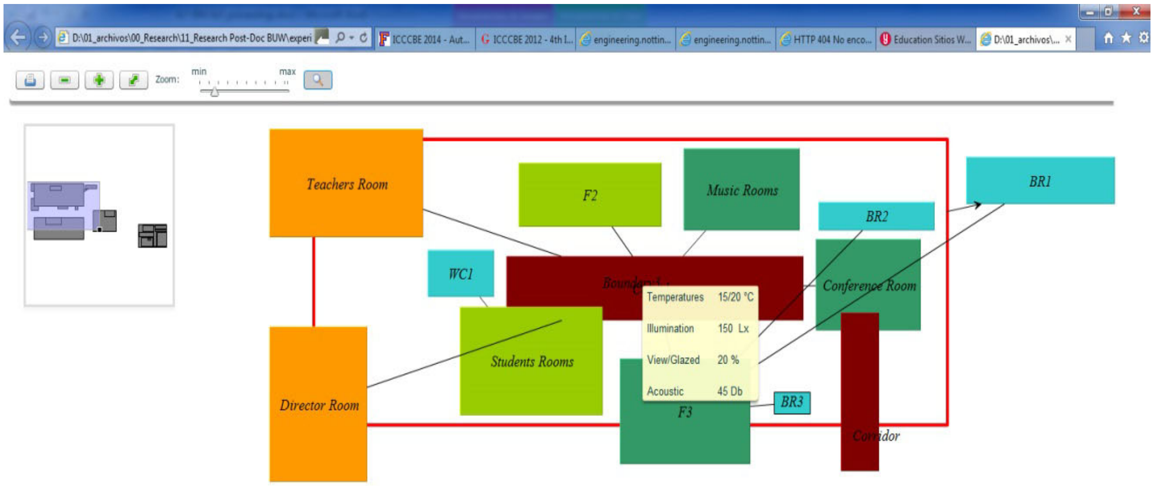

Figure 4. Visualization of performance parameters (yellow window in the center) for a corridor during design stage of the school. Source: Own Elaboration

CONCLUSIONS

A missing link between Building Information Modeling (BIM), Space Layout Planning (SLP) and Building Performance Simulation (BPS) has been detected. The possibility of creating a unified workflow was inquired and the possibility of linking BIM+SLP has risen to support the creation of architectural floor-plans. Real variables from real cases have been utilized to show architects the performance parameters that must be fulfilled by the rooms (according to Chilean Building Performance Regulations) during the schematic floor-plan design stage. The information is added to a graph and then visualized in real-time, then architect can make better decisions.

The edition of graphs allows designers to put and use complex information in the early stages of architectural design. Regulations and norms from different countries can be accessed and entered to the system.

Variables of performance parameters were shown as an example; nevertheless the concept can be expanded to orientation, minimum/maximum room size, finishing materials and many others. Indeed an important link between different fields related to building cycle can rise. That means a great potential of integration between architects and consultants (light, acoustic, thermal, envelopes, etc).

OUTLOOK

For the future the integration to BIM (Building Information Modeling) software is expected. C# (C Sharp) programming language is currently being successfully tested to prove this concept within BIM software Autodesk Revit Architecture. To the date of submission a plug-in for Autodesk Revit has been successfully developed, but still not testes. On the other hand improvements such as: ease of graph edition, connection with several external official data bases with parameters and values, decision-making support by optimization, and self-generation of layouts are expected.

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