INTEGRATED MODEL SUPPORTING ENVIRONMENTAL PERFORMANCE SIMULATIONS IN THE EARLY STAGES OF BUILDING DESIGN

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ABSTRACT

Recent researches propose the integration of performance analysis to early stages of the design process in order to obtain the building´s best final performance (Kolarevric; Malkawi, 2005; Holzer, 2010; Oxman, 2007). Thus, choosing the appropriate set of solutions and digital tools to develop this task is of high complexity and responsibility. The main objective of this paper is to identify and characterize the evaluation of different performances in social housing design stage, through the development of a model containing appropriate abstractions, for the representation of valid and accurate analytical data as inputs and outputs to specific simulations. This study was developed as field study involving experts in the area of thermal comfort, acoustic comfort, lighting comfort, materials conservation, water conservation and accessibility. The results show strengths and difficulties for integrating performance analysis focusing the information modelling and interoperability between computational simulations. A sequence for performing simulations considering inter-influences is proposed. This paper contributes with the characterization of the ideal information model to be use in different simulation tools, during the design stage of social housing solutions; promoting quality improvement related to social housing and the use of BIM (Building Information Modeling). Therefore instigating the increased use of simulation tools and information technology in construction during the design process.

INTRODUCTION

Several design researches agree that design development requires a sequence of decisions to construct a specific problem solution (Lawson, 2005; Wood; Gidado, 2008). In building design, it is the designer's task to present solutions that attempt to technical and functional performance in accordance to the economic focus proposed by the client (Rosso, 1980; Kalay, 2004). In addition, these solutions must attend to the several interdisciplinary variables.

Especially about architecture, the performance concept involves different ranges, from the aesthetic to the purely technical (Kolarevric; Malkawi, 2005). So, some of these requirements are based on quantitative parameters and, therefore, easier to value. In the other hand, there are also requirements based on qualitative parameters, as human behaviour and perception.

To the questions related to the technical performance, quantitative, testing the proposed solutions by the computational tools utilization, as a predictive evaluation of the proposed solution set performance, reduces the process time and helps the decision making to determine the most adequate solution, even at the early stages. It can be said that the performance simulation is also able to anticipate deficiencies identification, reducing process or even post production costs.

Marsh (1997), Kalay (1999), Soebarto (2001), Giannantoni et al (2005), Struck e Hensen (2007), Alucci (2007) and Petersen e Svendsen (2010) present methods for integrated analysis of design parameters related to environmental performance. These methods are susceptible to direct confrontation with simulation tools and digital evaluation searching for the most appropriated solution, especially at initial design stages, when big modifications can be studied, and several restrictions restudied or even surpassed, maximising user comfort efficiency in the proposed conjunction.

Computer simulation supporting design decisions evaluation exists within both CAD (Computer Aided Design) and BIM process. The difference in BIM lies on the emphasis given to information model reuse by the interoperability and a unique data basis. A single solution must be submitted to several simulations, therefore different applications and the used model must act like unique data basis that contain all the information needed to the different analyzes. Therefore, multiple software used must present an exchange pattern mutually supported. According to Kolarevic and Malkawi (2005), this need made possible the environments and platforms development which can promote the project analyzes integration based on semantic representations that support the objects data integration. The most independent exchange format nowadays is the Industry Foundation Classes (IFC), able to maintain the associations between whole model and the simulated.

This article presents a study dedicated to the identification of the information model necessary to support different analyzes in early conceptualization of social housing typology. In order to integrate different and understand multiple performances specialists of thermal, acoustic and lightning comfort, material resources and water conservation, and accessibility were interviewed. The research main objectives are:

- To propose a model that contains adequate abstractions, working like an analytic valid and accurate project data representation for the inputs and outputs, in social housing.
- To enumerate variables and confront them in order to systematically optimize performances.

RESEARCH APPROACH AND METHODOLOGY

The research has been carried out in two parts. The first part consisted of a Building Performance Simulation literature review, necessary to understand the problem. In addition, the review indicated a set of criteria for data collection and analysis. The second part included interviews with experts in the area of thermal comfort, acoustic comfort, lighting comfort, materials resource conservation, water conservation and accessibility.

Part 1: Criteria for data collection and analysis

The literature review identified several approaches for "Integrating Building Performances". Those that have excelled were: Criteria for Building Performances; Multi-Performance; Evaluation for Building Performance and Building Performances Tools. All of those in order to guarantee the correct identification of environmental performance parameters associated with social housing designing.

Part 2: Interviews

The interviews aimed to compare specialists' perceptions on different performances analysis for social housing. The interviews were conducted within a specific group of experts, one for each of the disciplines: acoustic, thermal, lightning and functional performance (focusing on accessibility and sustainability), water consumption and material durability.

The interview included open questions in order to allow respondents to share their thoughts and comments. The average duration for the conversation was from 30 to 45 minutes. The questionnaire was structured into 4 parts as Table1.

Table 1
Guide questions of interviews

1 - CRITERIA FOR BUILDING PERFORMANCE
How are performance criteria of your specialty involved in the early design stage?
2 - MULTI-PERFORMANCE
Is there interference between building performance of your speciality and any other?
3 - EVALUATION FOR BUILDING PERFORMANCE
Which are the evaluation method or design analysis used in your speciality?
4 - BUILDING PERFORMANCE TOOLS
Is there a computational tool that supports this process?

RESULTS

Notes were taken during interviews and answers to guide questions were compared between specialists in the search of common or specific evaluation parameter.

Part 1 - Criteria for Building Performance:

How are performance criteria of your specialty involved in the early design stage?

Each expert identified important analyzes scopes in the early design stage for the implementation of housing projects, and factors that influence specific performances. Comparison and synthesis of answers to this specific question identifies the set of global influencing factors (evaluation parameters) and its incidence in different performance scopes (Table 2). The vertical totalling of parameter indicates performance evaluation that requires most information. The horizontal totalling indicates reuse of parameters between different types of evaluation.

Table 2
Evaluation parameters pointed to by specialists

PARAMETERS REQUIRED FOR EVALUATION	A	Ac	Lc	Tc	Mc	Wc	OCCURRENCE
Openings (opn)	0	1	1	1	0	0	3
Permeable Areas (par)	0	0	0	0	0	1	1
Rainwater harvesting (rha)	0	0	0	0	0	1	1
Toppings (tpp)	0	0	0	1	0	0	1
Climatic Conditions (clc)	0	0	0	1	0	1	2
Access Control (act)	1	0	0	0	0	0	1
Control Gaps (ctg)	1	0	0	0	0	0	1
Hydraulic Economizers (hye)	0	0	0	0	0	1	1
Spacing between buildings (sbb)	0	0	0	1	0	0	1
Around (ard)	0	1	1	0	0	0	2
Artificial light source (als)	0	0	1	0	0	0	1
External noise source (ens)	0	1	0	0	0	0	1
Source of internal noise (sin)	0	1	0	0	0	0	1
Natural light source (nls)	0	0	1	0	0	0	1
Geometry (geo)	1	1	1	0	1	0	4
Stormwater Infiltration (sti)	0	0	0	0	0	1	1
Materials (mat)	1	1	1	1	1	0	5
Individualized Measurement (idm)	0	0	0	0	0	0	0
Guidance (gui)	0	1	1	1	0	1	4
Stormwater retention (str)	0	0	0	0	0	1	1
Water reuse (wtr)	0	0	0	0	0	1	1
Topography (top)	1	0	0	0	0	0	1
Volumetry (vol)	1	1	0	0	1	0	3
TOTAL	6	8	7	6	3	8	

Legend: Accessibility (A), Acoustic Comfort (Ac), Lighting Comfort (Lc), Lighting Comfort, Material Conservation (Mc), Thermal Comfort (Tc), Water Conservation (Wc). For answers: no = 0; yes=1.

The Figure 1 presents the evaluation parameter for identified scopes of performance analysis study for social housing pointed by specialists. Accessibility Performance (A): *Guarantee the universal right to come and go*; Acoustic Comfort Performance (Ac): *Control of airborne noise or impact, internal or external*; Lighting Comfort Performance (Lc): *Ensuring adequate level of illuminance (lux) without solar gain*; Thermal Comfort Performance (Tc): *Climate control in indoor environments in winter and summer*; Water Conservation Performance (Wc): *Ensuring rational use and conservation of water*; and, Materials Resource Conservation Performance (Mc): *Reducing the amount of material consumed for construction*.

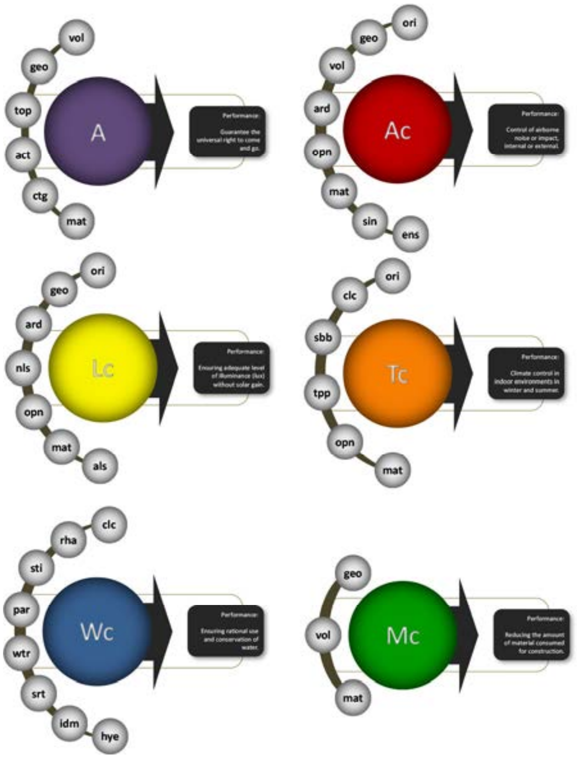

Figure 1 Performances factors and scopes models

Part 2 - Multi-Performance:

Is there interference between building performance of your speciality and any other?

Each expert was asked if the building performance of their speciality suffered interference of other performances. Again answers were compared (Table 3) resulting in the scheme interference presented in Figures 2 and 3. According to Table 3, acoustic performance suffers most interference from others studied performances. Again, acoustic comfort, but also lighting comfort, influences most other studied building performances for social housing.

Table 3
Interference between performances studied

	A	Ac	Wc	Mc	Lc	Tc	Influence
Accessibility (A)	0	1	0	0	1	0	**2**
Acoustic Comfort (Ac)	1	0	0	1	1	1	**4**
Water Conservation (Wc)	0	1	0	1	0	0	**2**
Materials Resource Conservation (Mc)	0	1	0	0	1	1	**3**
Lighting Comfort (Lc)	1	1	0	1	0	1	**4**
Thermal Comfort (Tc)	0	1	0	1	1	0	**3**
Suffers Influence	**2**	**5**	**0**	**4**	**3**	**3**	

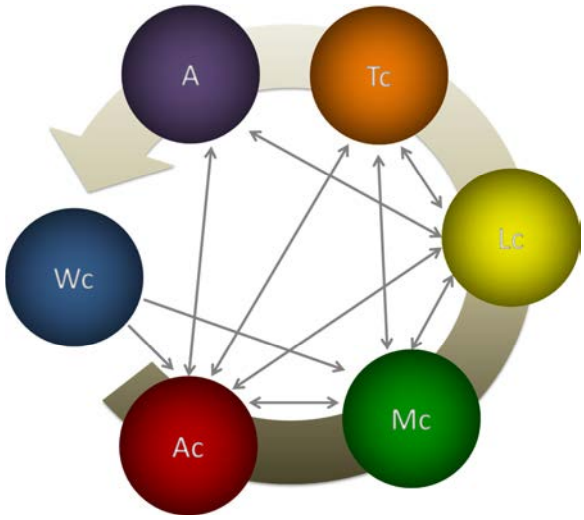

Figure 2 Influence relationship between the performances: counter clockwise of more to less influenced

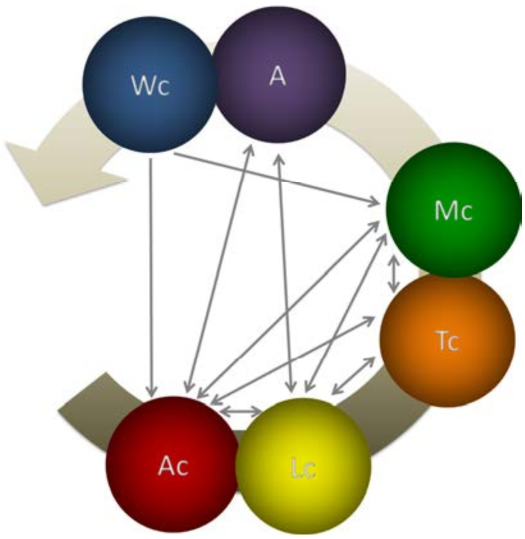

Figure 3 Influence relationship by pairs between the performances: counter clockwise form more to least influence

Part 3 - Evaluation for Building Performance:

Which are the evaluation method or design analysis used in your speciality?

Each expert was asked about the method of assessing the performance of their expertise in early design stage for social housing. It was observed, that interviewed specialist, realize evaluations by analytical procedures and physical simulations (Table 4). There is few interaction of computational tools, although there`s knowledge of its use in this design stage.

Table 4
Methods for Evaluation of performance at design stage

	A	Ac	Wc	Mc	Lc	Tc	Methods
Analytical Analysis (calculations)	0	1	1	1	1	1	**5**
Project Analysis (visual)	1	0	0	0	1	1	**3**
Simulation Tool (physical models)	1	0	0	0	1	1	**3**
Simulation Tool (known computer models)	0	1	0	1	1	1	**4**
Simulation Tool (Uses computer models)	0	0	0	0	0	0	**0**
Used methods / performance	**2**	**2**	**1**	**2**	**4**	**4**	

Part 4 - Building Performance Tools:

Is there a computational tool that supports this process?

Each expert was asked about the computational tools for evaluating the performance of their expertise in the early design stage. The tools mentioned by respondents were:

- Acoustic Comfort: Bastian, EASE, Odeon and SonArchitect;
- Thermal Comfort: Ecotect, EnergyPlus (for later stages);
- Lighting Comfort: DAYSIM;
- Accessibility: none indicated;
- Water Consumption: none indicated;
- Material Consumption: ENVESTII.

DISCUSSION AND CONCLUSION

In this study six specialists were interviewed. The significance of the results cannot be calculated and results cannot be generalised. However, the method can be applied to guide interaction between a given group of specialists for building design with environmental performance emphasis. In this case the experts were professors and researcher in the area of thermal comfort, acoustic comfort, lighting comfort, materials resource conservation, water conservation and accessibility.

It was possible identify an integrated model supporting environmental performance simulations in the early stages of building design (Figure 4). However, considering the unavailability of a unique computational tool able to integrate different evaluation and to show the impact caused by the change of a specific parameter over another, the presented model is never used as a whole. However, it indicates what information is needed in order to prepare correct information models for BIM simulation tools.

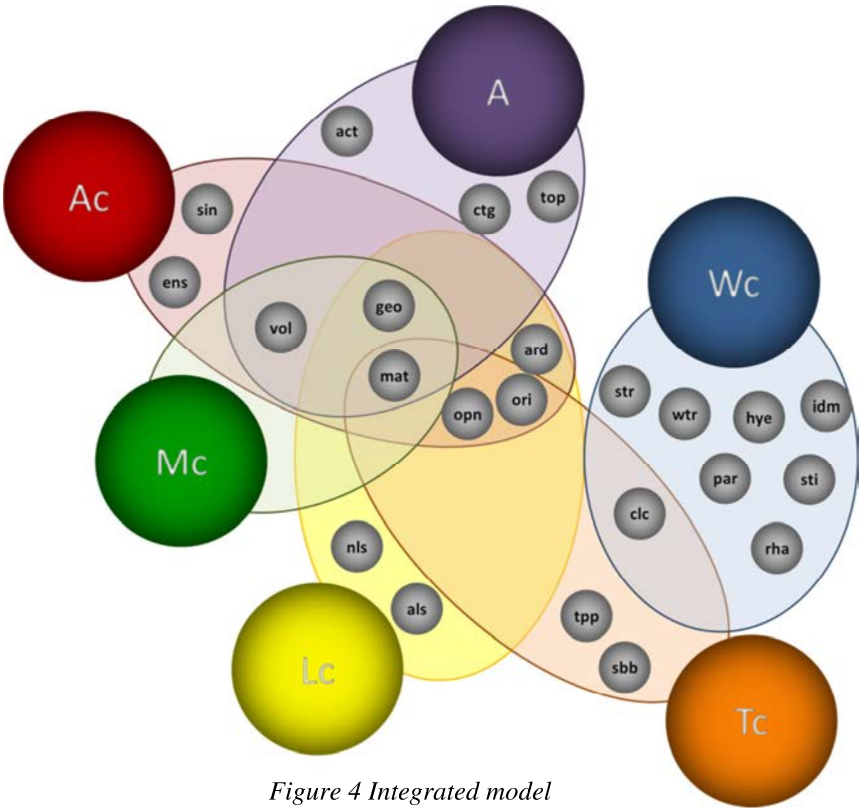

Figure 4 Integrated model

The influence of the established performances relationship can point to a simulation methodology for the studied typology. The organization starting by the least influenced, to the most influenced (Figure 5) can indicate a sequence of simulations e decision-making. While the reverse organization order, can indicate the starting point for the project process, by the elimination of restrictions.

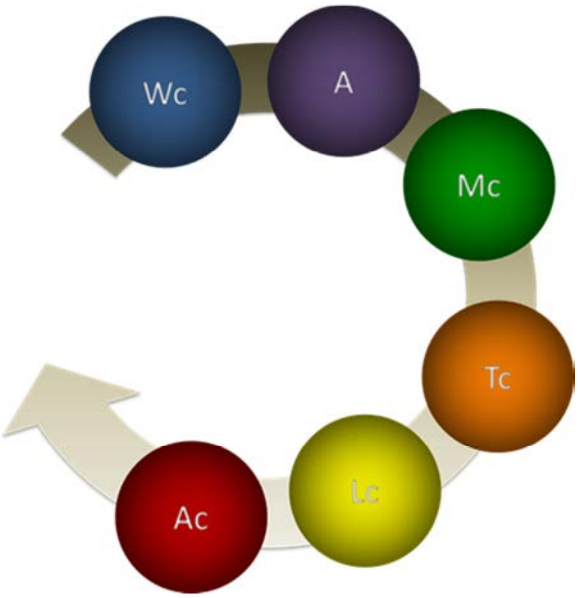

Figure 5 Sequence of simulations e decision-making

It was observed that computational simulation is poorly incorporated at the initial design stages, despite the recognition of its existence and usefulness. Analytical methods are mostly used. It is suggested that in Brazil design process is based on a theoretical legacy, where the decisions are taken in an isolated and hierarchical way.

Related to the mentioned performances simulation tools, it can suggested that some producers have more computationally developed than others, like acoustics and thermals performances. Although most of the available tools, for these performances, are developed for later stages of the design process.

NOMENCLATURE

A = Accessibility
Ac = Acoustic Comfort
Lc = Lighting Comfort
Mc = Material Conservation
Tc = Thermal Comfort
Wc = Water Conservation
opn = Openings
par = Permeable Areas
rha = Rainwater harvesting
tpp = Toppings
clc = Climatic Conditions
act = Access Control
ctg = Control Gaps
hye = Hydraulic Economizers
sbb = Spacing between buildings
ard = Around
als = Artificial light source
ens = External noise source
sin = Source of internal noise
nls = Natural light source
geo = Geometry
sti = Stormwater Infiltration
mat = Materials
idm = Individualized Measurement
gui = Guidance
str = Stormwater retention
wtr = Water reuse
top = Topography
vol = Volumetry

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