Contribution for Integrating Energy Simulation into the Building Design Process

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Abstract

Building energy simulation is a new topic in the Brazilian civil construction market. Therefore, it is important to investigate how to integrate this new activity into the building design process. A necessary step to advance in this direction is to map the building energy simulation process. For that purpose, a literature review was carried out on concerns regarding energy conservation, energy simulation and challenges in the building design process in the Brazilian market. An exploratory research was then developed, including semi-structured interviews with the energy and mechanical/electrical/plumbing (MEP) manager of a consulting firm in São Paulo city and the analysis of documents related to a commercial building. Energy simulation process mapping can help designers to understand: the relationship of simulation and design disciplines; simulation as a process (input – processing – output); the responsibilities involved in data simulation and how to organize them to other players; the importance of providing simulation data input.

Keywords: Integration, process, mapping, environmental requirements.

1. Introduction

In Brazil, actions related to energy conservation began to be taken, motivated by the 2001 Brazilian energy crisis, when the first energy law was approved. In 2003, the National Program for Energy Efficiency in Buildings (PROCEL EDIFICA) was established to promote electric power rational use. PROCEL EDIFICA contributed to the development of reference parameters for checking the level of buildings energy efficiency, which originated the Quality Technical Regulation for Energy Efficiency Level of Commercial, Services, Public and Residential Buildings (RTQ-C) and the Conformity Assessment Requirements for Energy Efficiency Level of Commercial, Service, Public and Residential Buildings (RAC-C), both published in 2009 (FOSSATI, MORISHITA and LAMBERTS, 2011; MELO et al., 2012; SCALCO et al., 2012).

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RTQ-C specifies the technical requirements to classify the buildings energy efficiency level in order to label them. The buildings can be classified into five levels – from "A" (most efficient) to "E" (least efficient) – based on two approaches: simulation or prescriptive method. The building labelling process is composed of two stages specified in RAC-C: design assessment, whereby a design label can be issued; building inspection, whereby the building can obtain the label (FOSSATI, MORISHITA and LAMBERTS, 2011; SCALCO et al., 2012). According to Inmetro (2012), one in thirty-five commercial, services and public buildings labelled at the design stage was assessed by the simulation method, and the prescriptive method was utilized in all residential buildings and multifamily buildings (twelve design labels were issued).

As stated by Mendes et al. (2005), building simulation use in Brazil is still concentrated in educational and research institutions with little technology transfer to the private sector. Nevertheless, there is a trend for change since there is the market demand for buildings labelled or certified by LEED (Leadership in Energy and Environmental Design), AQUA Process (High Environmental Quality of Buildings, an evaluation and certification methodology of sustainable buildings of French origin used in Brazil), among others. Cavalcante (2010) says that ASHRAE 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings, referred in LEED, has gained acceptance in recent years in Brazil, specifically in São Paulo city, and consulting activities have been hired to demonstrate building compliance through simulations.

Energy simulation is a new topic in the Brazilian civil construction market. As a consequence, the energy simulation process is not yet mapped; information used in simulation is dispersed and the sustainability consultant needs to seek data in the several design disciplines. Moreover, simulation is also a new activity in the designer sphere, which had not been previously required. Hence, it is important to investigate how to integrate this new piece into the puzzled building design process. For that purpose, it is necessary: (1) to map the energy simulation process (input – processing – output), (2) to map the design process (input – processing – output), (3) to identify interfaces and difficulties between the design and the simulation processes, (4) to define strategies to integrate the new activity into the design process, (5) to test the strategies and (6) to validate them.

In Brazil, there is lack of a building design process reference. Although there are some standards related to design and free design scope manuals created by Brazilian entities that represent the design professionals, they are not applied by them. It is important to highlight that the standards are outdated. Melhado (1994) emphasizes that the standards should be reviewed in order to add some concepts, such as multidisciplinary approach, constructive rationalization and buildability. New demands should be inserted in the standards and manuals: building integrated design, building environmental sustainability, building performance standard and Building Information Modeling (BIM).

The Brazilian reality is different from other contexts. In the British case, for example, the building design process was mapped, resulting in a document called Outline Plan of Work, which was reviewed with BIM and Green Overlays. These documents can be downloaded for free (RIBA, 2012); they are references to the players involved in the building production.

Paula and Melhado (2012) state that the effects of environmental sustainability demands on the building design stage are: consulting firm participation in the project team, to promote the inclusion of environmental requirements at the design stage; inclusion of new players in the design team, such as acoustic and sanitary engineers; changes in contractual requirements, as designers should be aware that there are sustainability requirements in the project; inclusion of environmental requirements into the design, which should be coordinated also with that specific focus; use of new technologies, both incorporated to the buildings and to the design stage, such as use of BIM and simulation tools; and recognition of the importance of the design stage and integrated design.

In addition, Paula e Melhado (2012) present the challenges and questions: the design process is not defined - there is a lot of rework in the design tasks; the scope of the players involved in the project is not defined - what are the responsibilities of each player and the scope of the designers?; should new competences be developed according to the demand for environmental sustainability?; the time of the use of simulation tools and their results should be defined to facilitate decision making; current demands and their interrelation should be considered in the design process, such as environmental certifications, PROCEL EDIFICA, performance standard and BIM.

All of this is complex as a whole; it is necessary to break this context down into parts that allow understanding of the design process, the new demands and the relationship among them. Thus, our aim is to map the building energy simulation process, one point necessary to integrate it into the design process.

2. Research method

The research method used was the exploratory research. According to Gil (2008), this type of research provides more familiarity with the problem studied, making it more explicit and allowing hypotheses delineation. The main purpose of exploratory research is to allow ideas to be improved or insights to be had. The planning for data collection is very flexible, making it possible to consider various aspects related to the fact studied.

Two semi-structured interviews were conducted with the energy and MEP (Mechanical Electrical Plumbing) manager of a consulting firm in the São Paulo city. In addition, the documents related to building energy simulation– a commercial building seeking LEED certification - were analyzed. The aim was to understand the energy simulation process followed by the consulting firm. As shown in Figure 1, this paper contributes to the first stage towards integrating energy simulation into the building design process.

A literature review was carried out regarding the Brazilian concerns about energy conservation, energy simulation in the Brazilian market and challenges in the building design process.

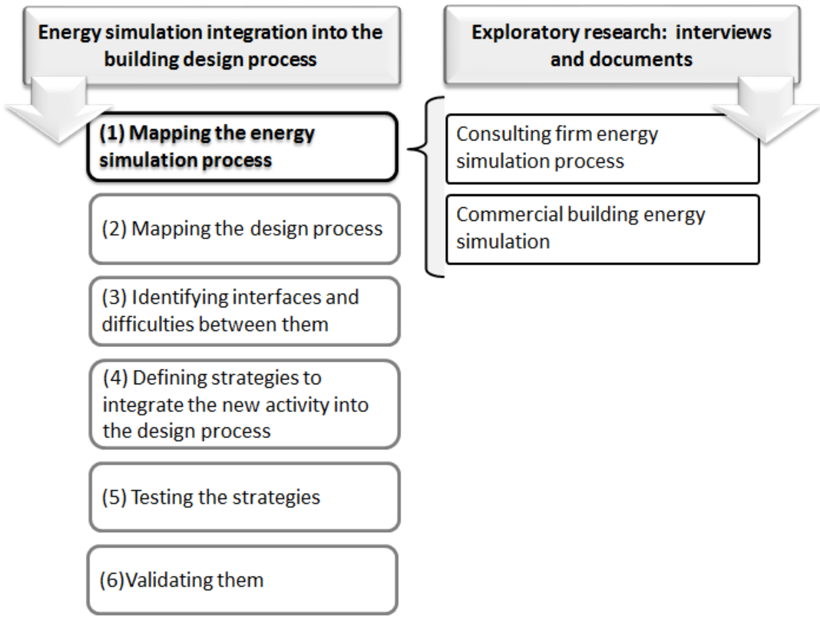

Figure 1: Stages to the energy simulation integration into the building design process

3. Exploratory research

3.1 Building and consulting firm characteristics

The consulting firm characteristics were obtained through the interviews and its website. This firm was chosen due to its relevance in the Brazilian market. It has been in the market since 1990, has approximately 130 employees, and is also ISO 9001, ISO 14001 e OHSAS 18001 certified. Nowadays, it works in six areas: business consulting, sustainability, management, real estate, events and courses and web applications. Its clients are investors, developers, construction firms, design firms, material manufacturers and government agencies, among others.

The building of reference, currently at construction stage (building foundation), is inserted in the commercial market segment and aims at LEED Gold certification level. Its built area is 61.240 m², distributed in 4 underground parking, ground floor, 2 mezzanines, 31 floors type, engine room and attic. The project team was composed of the following players: real estate developer, construction firm, design firms and consulting firms.

3.2 Energy simulation in the building design process

The interviews allowed obtaining a set of considerations that are summarized as follows. As stated by the energy and MEP manager, his team usually uses the software Energy Plus. However, he is analyzing the possibility of using the software IES <VE>, because its graphical interface is more intuitive than that of EnergyPlus. EnergyPlus was the first tool used in the company and because of the large number of contracts aimed at LEED certification, its professionals have created an extensive database of this software.

According to the interviewee, regarding the moment for the energy simulation team to participate in the design process, in most cases the firm is contracted at the beginning of the design. The client hires the consulting firm to guide the design team to adequately consider environmental requirements in the building conception. The interviewee highlighted the importance of the architectural conception stage, a moment at which important decisions are made, such as building orientation and geometry, which greatly influence subsequent decisions.

In most cases, the consulting firm is hired by a developer, but construction or architectural firms also play this role. In the past, when the firm started the certification-related works, some clients hired it at the detailing design stage or with the construction in progress. In these situations, the consultants perform a diagnosis to analyze the possibility of the building obtaining the certification and the potential contribution of the simulation to evaluate alternative design solutions is rather limited. The interviewee exemplified two building cases in which the consulting firm was hired at an unsuitable time: in one case, based on the diagnosis, the certification could not be granted and the client opted to desist of the certification process; in the other case, the consulting firm was hired late at the design stage, which caused a lot of rework to finally achieve certification.

According to the interviewee, when the energy simulation occurs at beginning of the process, the consulting firm can provide an appropriate feedback to the design team. Currently, he has observed that designers await input from simulation results (feedback from consultants) to specify equipment, fixtures etc. Also, he highlighted other important points to the design stage success: design process management, activity planning and design coordination.

3.3 Energy simulation process mapping

The consulting firm suggests three energy simulations per building: preliminary, at the end of the preliminary design; intermediate and final simulation. At least two simulations must be performed: a simulation for the preliminary analysis of the building energy performance and proposition of improvements to the design, and the final simulation, as required by the environmental certification process. Simulation yield is defined in contract, and depends on the building complexity and the client requirements; some clients may require two, three or four simulations.

Figure 2 presents the energy simulation process mapping composed by inputs to perform the simulation, data processing in the design disciplines – architectural design, air conditioning design, lighting design and electrical design along with general data – and outputs from the process.

In the preliminary design stage, the designers are able to provide inputs for preliminary energy simulation. Regarding the information level, the interviewee said that the design information in a given stage varies greatly across design practices. The consulting firm receives the designs from different specialties and fills a, Energy Efficiency Simulation Data Form, normally used for commercial buildings, but adaptable for residential buildings and hospitals. As explained by the interviewee, filling the form was required from designers, but they did not carry out this activity.

The consulting firm just sends the form to the designer in case it needs specific data and, if necessary, designers perform some calculations and estimates. Therefore, when concluded, the form is validated often by e-mail by all professionals, including the clients, since they must be aware of the input data used in the simulation.

Energy Simulation Process	Inputs	What to considerar...	Design Disciplines					Outputs/ Activities
			1. ARC	2. AIR	3. LIG	4. ELE	5. Gen. Data	
1.1	Facades	Ground plan and sections of the building and facades						Annual consumption and cost of energy Building performance analysis Proposition of energy efficiency strategies Energy Efficiency Technical Analysis Report [Simulation]
		Solar protection devices						
		Specification of the facades and exterior wall materials						
		Specification of the facades glazing						
1.2	Roof	Specification of the roof						
		Zenithal daylighting or skylights						
2.1	System composed of Chillers	Chillers circuits						
2.2	Direct expansion system	Condensing units						
2.3	System for distributing air conditioning	Fan-Coil equipment						
		Thermal zoning by VAV boxes						
		Thermal zoning by raised floor system						
2.4	Mechanical ventilation systems	External air intake						
		Bathroom exhaust or purge (central or individual)						
		Garages exhaust						
		Stairs pressurization						
2.5	Energy efficiency strategies for air conditioning system	Enthalpy wheel (sensitive and latent heat)						
		Individual heat recovery (sensitive heat)						
		Control of external air intake in relation to CO_2						
		Control of garage exhaustion in relation to CO						
		Chilled water thermal storage						
		Ice thermal storage						
		Use of gas absorption chillers in peak shaving						
		Pretreatment of outside air (cooling/ dehumidification)						
		Saving cycle						
		Free-cooling						
		Co-generation with absorption chillers and gas generators						
		Night-cooling						
3.1	Indoor lighting	Lighting power density considered (W/m^2) or total power considered per area (W)						
3.2	Exterior lighting	Lighting power density considered (W/m^2) or total power considered per area (W)						
3.3	Energy efficiency strategies for lighting	Lighting dimerization for daylight use						
		Automatic shutdown of lighting by photoelectric relay						
		Presence sensor in all indoor areas						
		Presence sensor in garages						
4.1	Lifts	Number of lifts (social, service etc.)						
		Nominal power unit (KW or CV)						
4.2	Escalators	Number of escalators (social, service etc.)						
		Nominal power unit (KW or CV)						
4.3	Hydraulic pumps	Number of operating pumps of cold water, rain water, waste water, water for irrigation, water for ETE / ETA						
		Nominal power unit (KW or CV)						
4.4	Energy efficiency strategies for electric	Lifts with regenerative braking						
		Lifts with early call system						
		Escalators activated by presence sensor						
5.1	General data	Climate file (temperature data of dry bulb and wet bulb, atmospheric pressure, wind, solar radiation and nebulosity)						
		Electricity rates						
		Occupancy and use patterns of the building						

(1) Architectural Design, (2) Air Conditioning Design, (3) Lighting Design, (4) Electrical Design, (5) General Data

Figure 2: Building energy simulation process mapping

Energy simulation, building performance analysis and energy efficiency strategies propositions are carried out resulting in the Energy Efficiency Technical Analysis Report [Preliminary Simulation]; it is composed by: (1) introduction, (2) data common to both models, (3) baseline data, (4) design data, (5) performance data and (6) concluding remarks. The form Data Form for Energy Efficiency Simulation is an appendix of this report. All data contained in the form, in compliance with the standards and from estimates and calculations, are necessary to perform the preliminary simulation. As a consequence of design evolution, there are changes and the data, previously estimated, needs updating. Thus, the difference among the simulations – preliminary, intermediate and final – is the refinement degree of the information inserted. The preliminary report simulation assists in data refining and closing, and provides feedback to designers, who can improve proposed solutions toward the detailed design stage.

3.4 Building energy simulation

Three energy simulation were predicted to the building – preliminary, intermediate and final simulations. The first simulation occurred at the end of the preliminary design.

According to the Energy Efficiency Technical Analysis Report [Preliminary Simulation], the building design was not complying with the goal of reducing 10% in annual energy cost as compared against the baseline model, required by LEED ® for Core & Shell (2009). For this reason, the consultants identified the items that influenced the building's performance and proposed a set of potential energy efficiency strategies. The main items were the window wall ratio in the facades and the glazing's solar factor, both above the ASHRAE 90.1 (2007) baseline.

After that, scenarios were created with the adoption of energy efficiency strategies, considering the same architectural design condition and keeping the facades and glazing options; technical options were inserted in relation to the air conditioning and lighting designs. The strategies were: (1) insertion of heat recovery in the HVAC system, in which the purged indoor air pre-cools the incoming external air; (2) variation of external air intake in each floor, depending on the CO_2 concentration in the spaces; (3) automated and motorized blinds implementation to reduce direct solar radiation gain; (4) fixture circuits dimerization next to the facade in order to use daylight and reduce energy consumption.

The report concluded that the conditions for improving the facade architectural design, along with specifying more efficient glazing would certainly contribute to the improvement of the building overall energy performance, due to the direct impact on reducing the power consumption of the HVAC system.

Subsequently, a facade study was ordered, also conducted by the consulting firm, but contracted separately. Study specifications were simulated (intermediate simulation). As demonstrated by the Energy Efficiency Technical Analysis Report [Facades Study], the evaluation of two types of laminated glass applied to the facades and atrium roof, and the use of automated blinds applied to the North facade was carried out, and the final glazing specification was provided by the architectural design practice.

Nonetheless, according to the report, the design was still not in compliance with the minimum goal of reducing 10% of the annual energy cost; there was the need to maintain the adoption of the strategies listed above. It was concluded that only with the adoption of North facade blinds, along with the use of heat recovery system as well as the dimerization next to the facade was it possible to comply with the minimum goal of 10%.

4. Results and discussion

As seen from exploratory study, there seems to be a growing demand by LEED certification in Brazil and, consequently, of interest in demonstrating building compliance with ASHRAE 90.1 through energy simulations. It also corroborates Cavalcante (2010) and Paula and Melhado (2012) statements regarding consulting firm participation in the project team promoting the environmental requirements inclusion at the design stage.

Paula e Melhado (2012) discussed the suitable time to perform energy simulations. Based on the interviewee experiences, the moment for the first simulation is right at the beginning of the design process (preliminary design), when the consulting firm can provide appropriate feedback to the design team. Otherwise, there will be a lot of rework or the building will not be certified. Simulation yield is provided in contract, but new organization forms of the design team could be discussed, in which the consultant works directly with the architectural firm in order to provide simultaneous and continuous feedback instead of three simulation times – preliminary, intermediate and final simulations.

Energy simulation is required by most environmental certification schemes. Despite the requirement, simulation should be discussed concerning building performance. Thus, designers, especially architects, could discuss the need of some studies with the use of software or not in the design conception, such as building geometry study, attempting to anticipate the concerns about energy efficiency and environmental requirements as a whole. In this way, it seems the consultant presence should be anticipated, too.

Energy simulation process mapping (Figure 2) is the first step toward definition of strategies to integrate energy simulation in the design process, which needs to be tested and validated. As demonstrated by Inmetro (2012) and Mendes et al. (2005), the energy simulation is a new activity in the Brazilian market. Thus, mapping can help designers to understand the relation of design disciplines with simulation; the simulation as a process (input – processing – output); the responsibilities involving data simulation and how to organize them with other players; the importance of providing data for the simulation.

As stated by Paula and Melhado (2012), there is a major challenge towards integration of energy simulation in the design process, as the building design process itself is not mapped in Brazil. Moreover, the standards are outdated and the manuals are not used. The interviewee recognized the importance of design process management, activity planning and design coordination. As a whole, this, therefore, presents a research opportunity.

5. Concluding remarks

The suggested procedure of mapping, identifying, defining, testing and validating strategies contributes to integration of new activities or requirements into a given process. In other words, it can be used to integrate energy simulation or environmental requirements in the building design process. This paper focused on the first step (Figure 1): the barriers that needed to be studied. The research will be continued, as the design process and the energy simulation process need to be discussed with the players involved in building production, in order to develop guidelines transferable to the market.

BIM has widely been discussed and one of its premises is integrated design. The mapping procedure is a stage until the time when there will be the expected maturity in the application of this concept.

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