UNDERSTANDING ENVELOPE DESIGN: SURVEY ABOUT ARCHITECTURAL PRACTICE AND BUILDING PERFORMANCE

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ABSTRACT

This paper is part of a research that aims to develop simulation methods to support the architectural design practice. To do that, we need to understand how envelope design decisions are taken, which methods are more frequently used and which design definitions are relevant to take specific decisions. An online survey was developed to get information about the design process of professionals who are involved with architectural design. The survey was responded to by 51 architect-designers, 55 architect-researchers and 28 consultants from various countries. Features from each category surveyed can benefit the proposition of simulation techniques to support architectural design.

INTRODUCTION

Besides the influence on qualitative aspects of the built environment, the architectural design can affect considerably the thermal and energy performance of buildings (Venâncio and Pedrini, 2009). Design decisions related to geometric definitions and constructions are inherent in design practice. However, the support to these design decisions is often limited. Architects take design decisions mostly based on general qualitative information, such as principles, precedents or intuition (Pedrini and Szokolay, 2005).

Although the use of principles can provide proper guidance to most design decisions, this information is general or vague and may be inadequate to represent more specific design situations. Similarly, hidden errors in precedent solutions can lead architects to make false assumptions – and transfer conceptual errors to future designs (Bay, 2001).

Computer simulation can enhance substantially the quality of design support. Simulation tools are gradually evolving, and new interfaces are friendlier to architects. However, the use of simulation as part of the architectural conceptual process still comes up against the lack of methods that are in tune with the way architects proceed.

The development of such method requires an understanding about how design decisions are taken and which design definitions are related to specific design decisions. The goal of the research presented here is to obtain and describe information concerning punctual aspects of the architectural design practice.

In order to obtain the required information, we developed an online questionnaire and forwarded it to specialized discussion lists. A similar method was successfully applied recently (Attia *et al.*, 2009). Online surveys are easier to spread and can reach wider samples in comparison to traditional methods.

The survey approached three professional categories: architect-designers, architects-researchers and design consultants.

Each category has a specific approach that can certainly support further investigations about how architects can use simulation as part of the design practice. Designers are directly involved with design decisions and presumably more able to deal with multiple design constraints, criteria and qualitative information. Researchers are more distant from professional practice but usually apply methods rigorously, using a wider range of technical and theoretical knowledge. Consultants have the technical expertise to support designers, despite the limited autonomy to affect directly the decision-making process.

METHOD

The main goal was to obtain information about how each category tackles architectural design decisions. The questionnaire was divided into three sections:

1) Sample identification: general information about background, professional experience and tools used.
2) Methods: information about when (in which design stages) and how (with which information/methods) are taken specific design decisions.
3) Design definitions: identification of relevant design definitions to take specific design decisions.

The survey was hosted at (E-Surveyspro, 2010) from November 2009 until April 2010. A link to access the questionnaire was sent to the following discussion lists:

- Conforto Ambiental (confortoambiental): researchers and architects from Brazil and South America.

- Building Simulation (Bldg-sim): consultants and researchers from several countries.
- Green Architecture: architects from several countries that share the interest in sustainable architecture.
- Virtual-sim: discussion list about the software IES-VE.
- IBPSA-USA: consultants from the USA.
- EnergyPlus support: users of the tool from several countries.
- BAYA: young architects from several countries.
- Talking about architecture: architects from several countries.

Altogether 15 questions were included in the questionnaire. Given the relatively high subjectivity of some of the questions, fields for comments were added in nine questions.

The survey had 130 valid and fully responded questionnaires, which were divided into three samples: 51 architect-designers (designers), 55 architect-researchers (researchers) and 24 design consultants.

SURVEY RESULTS

Section 1: Sample identification – General information

The sample of 51 designers is fairly diversified in terms of background (location and climate familiarity). Even though the regulations of each country can affect how simulation tools are used, we believe that design practices are more influenced by climate features. So, in order to ensure privacy for the respondents, the question about the location was defined as optional. Most designers (66%) are from South America, followed by 12% from North America, 6% from Asia and 2% from Europe. 12% did not provide a location. Around 35% of designers are more familiar with hot-dry climate, followed by 31% hot-humid, 28% temperate and 6% cold.

The vast majority of the 55 researchers surveyed are from South America (87%), while 8% chose not to answer the question. Around 38% of researchers are familiar with hot-humid climate, followed by 33% hot-dry, 27% temperate and 2% cold.

From the sample of 24 consultants, 34% did not provide location, 29% are from North America, 25% from South America, 8% from Asia and 5% from Europe. Most consultants (55%) are more familiar with temperate climate, followed by 23% cold, 18% hot-humid and 14% hot-dry.

Section 1 – Professional information

In order to obtain professional information from the samples surveyed, the elaboration of questions was based on the following topics:

- Professional qualification: attributes that professionally describe each sample.
- Design experience: years of experience with design and frequency of involvement with design activities.
- Simulation tools: simulation tools that are used to support design decisions.

To obtain professional information about each sample, a few attributes were listed and the respondents were required to select options that were applicable to their design practice.

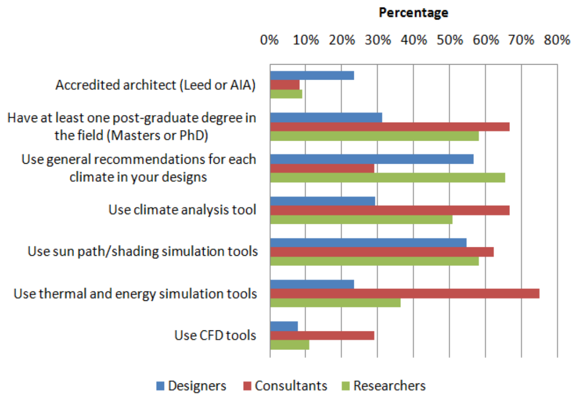

Figure 1 Professional qualification of the samples.

The following results can be highlighted (Figure 1):

- Designers: most designers are not accredited architects (76%) and are not involved with post graduate studies in the field (70%). The use of design recommendations, claimed by 58% of the sample, is more frequent than any tool. The use of simulation tools is limited, except for solar tools, used by 55%.
- Consultants: most consultants (67%) are post graduated in the field and use simulation tools. Thermal and energy assessments are more popular among consultants (75%), followed by climate analysis (67%), solar (63%) and CFD tools (55%).
- Researchers: 58% of researchers finished at least one post graduate study, which suggests that part of the sample was involved with a first research experience when the survey was available. Most researchers use the qualitative support of recommendations (65%). The use of solar tools (58%) and climate analysis tools (51%) is more frequent among researchers. The use of thermal/energy tools was claimed by 36% of the sample.

In order to identify the level of experience of the respondents, two criteria were considered: years of experience and frequency of design activities. The following results were obtained (Figure 2):

- Designers: most designers have up to five years of experience (57%), followed by 22% with 5-10 years and 22% with more than 10 years. 67% of the sample is frequently involved with design activities.

- Consultants: 67% of the sample has up to five years of experience and is frequently involved with design activities.
- Researchers: 44% of researchers have more than 10 years of experience, followed by 34% with up to five years and 21% with 5-10 years. Most researchers (72%) are occasionally involved with design activities.

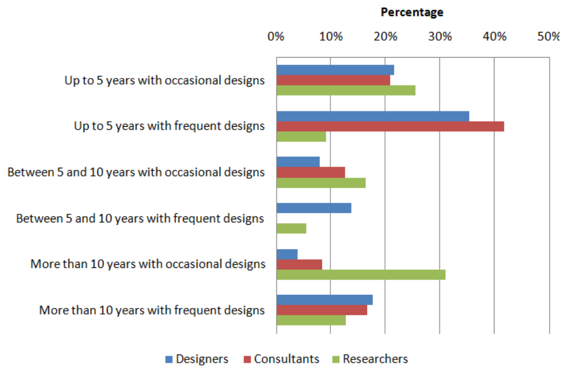

Figure 2 Design experience.

The use of simulation tools was also approached in the the first section. Respondents were asked to select the tool(s) used to support design decisions. The list of tools was partially based on a previous research (Attia *et al*., 2009). We added some tools according to the scope of assessments considered in the research, which includes climate analysis, solar, thermal/energy and CFD tools. The list has tools that are noticeably robust and/or friendly.

Some observations can be highlighted based on the results (Figure 3):

- Designers: compared to other categories, designers use less simulation tools. The most popular tools are ECOTECT SunTool (12%) and ECOTECT (10%). 55% of architects claimed not to use any simulation tools and 27% mentioned other tools that were not listed. Tools like TRNSYS, Energy-10, RESNET and custom spreadsheets had one mention each. Daylight tools and representation tools that are clearly not thermal simulation tools were also mentioned.
- Consultants: ECOTECT (38%) and EnergyPlus (38%) were the favorite tools. In addition to ECOTECT, other tools that are noticeably friendly, such as IES-VE and DesignBuilder, are relatively popular among consultants (each tool with 25%). 38% of consultants mentioned other tools. TRNSYS (12%) was the most mentioned.
- Researchers: EnergyPlus is used by 31% of researchers, followed by ECOTECT (25%), DesignBuilder (20%) and ECOTECT SunTool (16%). Other tools not listed were mentioned by 47% of the sample. However, 34% of the researchers mentioned tools that are not thermal simulation tools (daylight, representation or even methods borrowed from the literature).

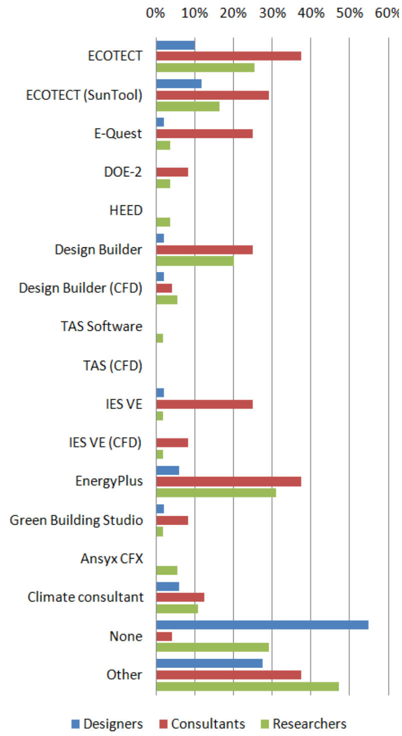

Figure 3 Simulation tools.

Section 2: Methods – Stages in which design decisions are taken.

Respondents were asked to identify when they usually tackle specific design decisions. The design process was divided in three stages (Morbitzer, 2003): outline design (early definitions), scheme design (design proposal) and detailed design (details of parts).

Table 1 Design stages in which decisions are taken.

		Outline	Scheme	Detail	N.A.
Form	Designers	94%	6%	0%	0%
	Researchers	87%	13%	0%	0%
	Consultants	58%	38%	0%	4%
Geometry	Designers	78%	20%	2%	0%
	Researchers	91%	7%	2%	0%
	Consultants	75%	25%	0%	0%
Walls	Designers	29%	57%	14%	0%
	Researchers	24%	65%	11%	0%
	Consultants	29%	46%	21%	4%
Roofs	Designers	22%	53%	24%	2%
	Researchers	38%	53%	9%	0%
	Consultants	8%	67%	17%	8%
External Colors	Designers	8%	31%	57%	4%
	Researchers	9%	51%	38%	2%
	Consultants	21%	21%	38%	21%
Glazing	Designers	8%	29%	55%	8%
	Researchers	5%	24%	56%	15%
	Consultants	17%	46%	29%	8%
Openings sizing	Designers	25%	63%	12%	0%
	Researchers	29%	67%	4%	0%
	Consultants	33%	54%	8%	4%
Shading devices	Designers	22%	55%	22%	2%
	Researchers	51%	44%	5%	0%
	Consultants	17%	63%	17%	4%
Internal layout	Designers	37%	45%	16%	2%
	Researchers	36%	60%	4%	0%
	Consultants	21%	50%	21%	8%

The percentages of each category are presented above (Table 1). The following aspects can be highlighted concerning each design decision:

- Form (2D planning): The vast majority of designers (94%) and researchers (87%) define the form in the outline stage, while a significant part of the sample of consultants prefers to tackle this definition in scheme design stage.

- Geometry (volume): although the three categories tend to define the building geometry in early design stages, this feature is more evident among researchers. Part of the sample of designers (20%) and consultants (25%) claimed to make volumetric definitions in scheme design.
- Walls (layers): most designers (57%) and researchers (65%) define walls in scheme design. Almost half the sample of consultants (46%) also tackle this definition in scheme design.
- Roofs (layers): the definition of roofs is made by all samples during scheme design stage (between 53% and 67%). A good part of the sample of researchers (38%) claimed to define roofs in outline design stage.
- External colors: most designers (57%) considered that these definitions are made in detailing stages. Around half of the sample of researchers (51%) claimed that this decision is made in scheme design stage.
- Glazing: the definition of glazing properties is a detailing design decision for most designers (55%) and researchers (56%). Around half of the surveyed consultants (46%) claimed to approach this definition in scheme design stage.
- Openings size: according to all categories, this definition is taken more frequently during scheme design stage (between 54% and 67%).
- Shading devices: most designers (55%) and consultants (63%) claimed to make the definition of shading devices in scheme design stage. The sample of researchers was divided between tackling these definitions in outline design stage (51%) or scheme design (44%).
- Internal layout: a considerable part of designers (45%), researchers (60%) and consultants (50%) claimed to tackle this decision in the scheme design stage. Part of the sample of designers (37%) and researchers (36%) considered that this definition is more frequently made in outline design stages.

Section 2: Methods – Information and methods used to support decisions

This section aims to investigate which information and methods are more frequently used by each category to tackle the following design tasks:

- Definition of climate strategies.
- Definition of form/geometry (in terms of solar exposure).
- Shading devices.
- Improve thermal performance.
- Analyze internal and external air flows.

We provided for each design task a group of methods and information. Respondents were asked to select how often they used each procedure by selecting one of the following options: 'frequently', 'sometimes' and 'not applicable'.

The focus of this section is to identify which methods or information are more commonly used by each category. The comparison, thus, takes into account the percentages of each sample that selected the item 'frequently'. In order to facilitate the presentation of results, the options divided in two categories: qualitative information (e.g. general knowledge, precedents, experience, etc.) and quantitative information (e.g. technical data, simulation tools, monitoring, etc.).

The first design task investigated concerns the definition of climate strategies. This process is related to the definition of some building elements, especially if they are designed as a clear response to climatic specificities.

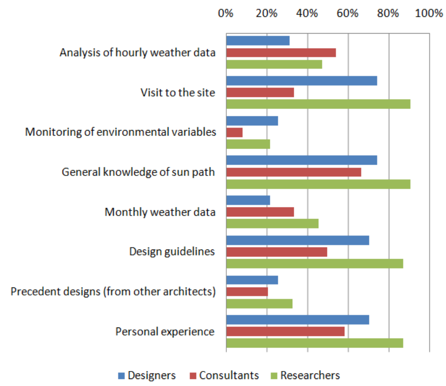

Figure 4 Methods and information frequently used to define climate strategies.

The following observations concerning the use of quantitative and qualitative information can be made based on the results (Figure 4):

- Qualitative information: researchers claimed to use frequently general knowledge of sun path (92%), visit to the site (92%), design guidelines (87%) and personal experience (87%) more than other categories. A fairly limited amount of designers (25%) and researchers (32%) claimed to make frequent use of precedent designs. According to the results not presented in the graph, 53% of designers and researchers use such information occasionally.
- Quantitative information: 54% of consultants, 47% of researchers and 31% of designers analyze hourly weather data frequently. Such information can be graphically translated by some tools (eg. climate analysis tools). This type of analysis also can focus on specific weeks or days that represent winter or summer conditions. The use of monthly data is less frequent for all categories in comparison to hourly data.

The second design task concerns the definition of the building geometry in terms of solar exposure. The following aspects can be emphasized (Figure 5):

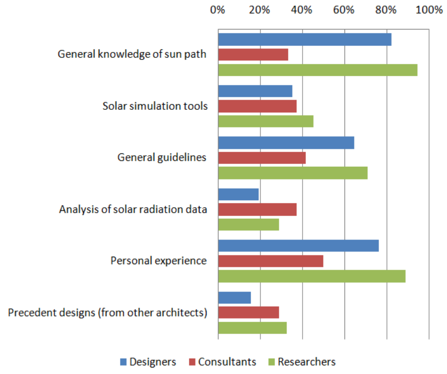

Figure 5 Methods and information frequently used to define the building geometry.

- Qualitative information: 95% of researchers and 82% of designers use frequently general notions of sun path. Knowledge extracted from personal experiences and design guidelines is also widely used by both categories. However, the use of design precedents is considerably less frequent.
- Quantitative information: 45% of researchers, 37% of consultants and 35% of designers frequently use solar tools (sun path and shading analysis) to define the building form/geometry.

The following observations can be highlighted concerning methods and informations used to design shading devices (Figure 6):

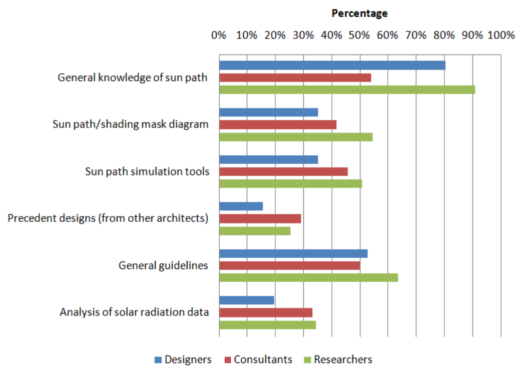

Figure 6 Methods and information frequently used to design shading devices.

- Qualitative information: 91% of researchers and 80% of designers use general knowledge of sun path. The majority of both samples (63% and 53%, respectively) frequently use guidelines to define shading devices.
- Quantitative information: 51% of researchers, 46% of consultants and 35% frequently use solar tools to design shading devices. The use of shading mask diagrams had similar percentages among three categories.

The following observations can be pointed out concerning methods and information frequently used to improve thermal performance (Figure 7):

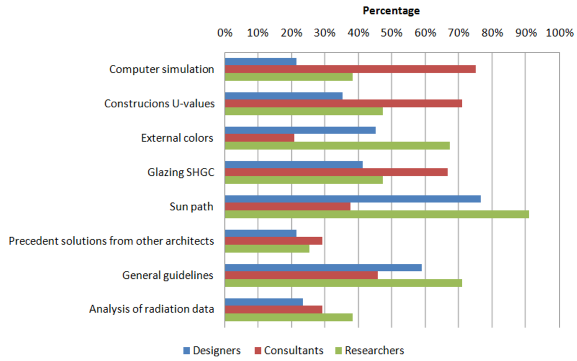

Figure 7 Methods and information frequently used to improve thermal performance.

- Qualitative information: most designers and researchers frequently use general information of sun path (76% and 91%) and design guidelines (59% and 71%). The use of precedent designs is less frequent to both categories.
- Quantitative information: the majority of consultants often use simulation tools (75%), U-values (71%) and glazing data (67%) to improve thermal performance. Among researchers and designers, the most frequently used technical information concerns the definition of external colors (absorptances).

Concerning the analysis of internal and external air flows, some points can be stressed (Figure 8):

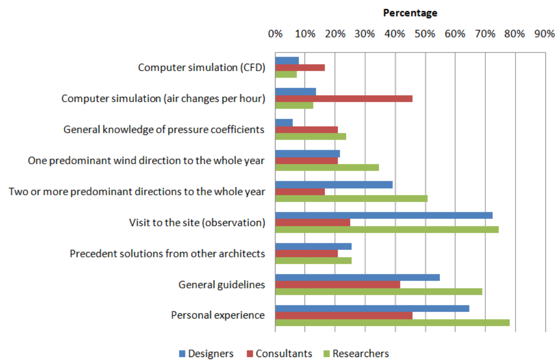

Figure 8 Methods and information frequently used to analyze air flows.

- Qualitative information: most researchers and architects use frequently information obtained by visiting the site (75% and 73%), personal experiences (78% and 64%) and design guidelines (69% and 55%). As identified in previous results, the frequent use of design guidelines is limited among both categories.
- Quantitative information: 51% of researchers and 39% of designers claimed to consider frequently two or more wind directions to analyze air flows. The percentages are slightly higher than the use of one wind direction. The simulation of air changes is frequently made by 45% of consultants and CFD simulation is made by 17%.

Researchers and designers support airflow decisions based on qualitative information.

Section 3: Relevance of design information - shading devices, walls/roofs and airflow decisions

The third section of the questionnaire aims to identify which design information is relevant and available to tackle design decisions related to solar, thermal and airflow analyses. Design definitions that are relevant to approach a given problem may have direct implications on the modeling process, especially during early design stages, when several design features are completely or partially unknown.

The relevance of design information is approached by three questions related to three types of assessment (solar, thermal or airflows). Respondents were asked to identify the relevance level of several design information to tackle the problem mentioned in each question. Three options represent the level of relevance: ' irrelevant or unavailable', 'sometimes relevant' and 'always relevant'.

Since the goal is to identify the most relevant design information, the comparison will focus on the responses of 'always relevant'. In order to facilitate the analysis, we defined two levels of relevance: very relevant (if results of 'always relevant' are higher than 70%) and relevant (if results of 'always relevant' are within the 50-70% range). The results of information considered 'sometimes relevant' is beyond the scope of this research.

The following design decisions were surveyed:

- Shading devices (related to solar assessments).
- Walls/Roofs (related to thermal assessments).
- Maximizing or controlling airflows within and around buildings (related to airflow assessments).

In order to design shading devices, the following definitions were considered most relevant (Figure 9):

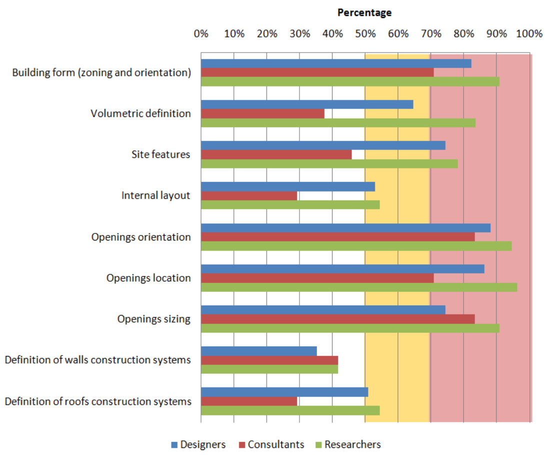

Figure 9 Relevant definitions to design shading devices.

- Very relevant for all categories: form (zoning and orientation) and openings orientation, location and size.
- Very relevant to designers and researchers: site features.
- Very relevant to researchers and relevant to designers: volumetric definition (geometry).
- Relevant to designers and researchers: definition of roofs.

The answers provided by designers and researchers were certainly influenced by the holistic nature of the design process, whereas consultants provided a more straightforward feedback.

Indeed, some definitions pointed out by designers and researchers, such as the definition of roofs, can occasionally influence the design of shading devices (as it can affect the building geometry).

Interestingly, the information considered most relevant (orientation and openings features) is the same input required by the ECOTECT SunTool module, which focuses on the design of shading devices. Of course, other decisions related to solar assessments might require more information about the geometry of the building, surrounding buildings or other types of information.

The second question focused on the definition of wall and roof properties in terms of thermal performance. The following design information was considered more relevant (Figure 10):

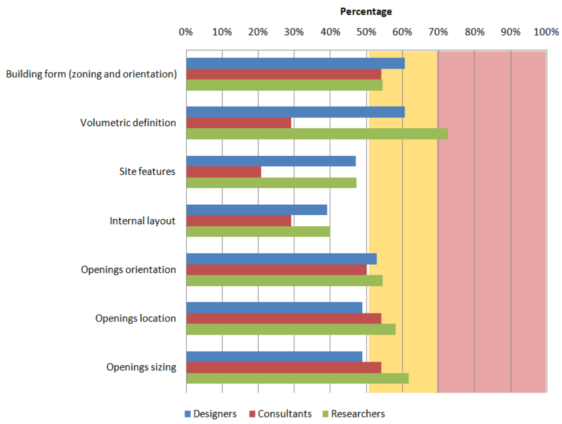

Figure 10 Relevant information to define walls/roofs.

- Very relevant to researchers and relevant to designers: volumetric definition.
- Relevant to the three categories: form (zoning and orientation) and openings orientation and size.

Results suggest that the technical definition of walls and roofs is fairly dissociated from other decisions. This definition can be supported by the actual properties of construction systems (e.g. R-values).

However, the quantification of the impact of such decisions using simulations would certainly require some (if not all) of the information considered more relevant (volumetric definition/form and openings features).

In order to take decisions related to maximizing or controlling air flows within and around the building, the following information was considered relevant (Figure 11):

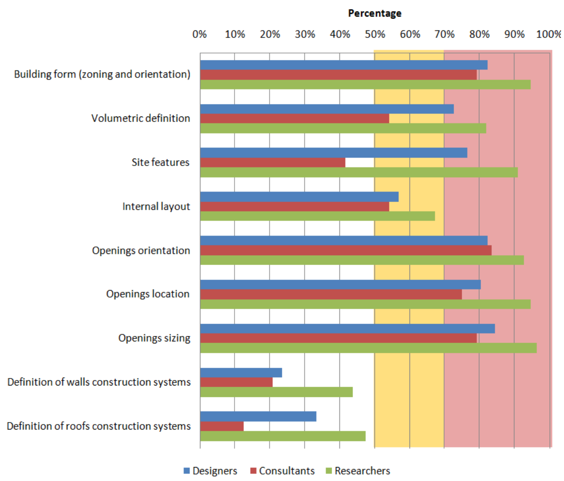

Figure 11 Relevant information to take airflow related decisions (within and around the building).

- Very relevant to the three categories: form (2D zoning/orientation), openings orientation, location and size.
- Very relevant to designers and researchers: volumetric definition and site features.
- Relevant to the three categories: internal layout.

We observe that consultants were more pragmatic as fewer design definitions were considered 'always relevant'. Researchers, on the opposite side, tended to select more information, even if the relation with airflow decisions is unclear. The definition of walls, for instance, was considered by 44% of researchers as 'always relevant'.

Airflow related decisions can be supported by CFD simulation (internal or external air flows) or air changes per hour calculation (for internal air flows). Each type of assessment can require different types of inputs and focus on specific aspects, but both rely strongly on geometrical information.

SIMULATION WITHIN THE DESIGN PROCESS

The results of the survey indicate that the use of building performance simulation (BPS) by designers and researchers is still limited, as suggested by previous works (Mahdavi *et al*., 2003). The design decisions are supported essentially by qualitative criteria that can be inadequate to specific situations.

Although consultants have the technical expertise to carry out computer simulations, the effectiveness of design support depends on the interaction between consultancy firms and designers. Consultants have limited autonomy to take design decisions and rarely have access to all subjective criteria used by designers.

Each category has features that can be merged and benefit the development of concepts to use simulation within the design process. The following assumptions investigated here are related to the use of simulation tools to support architectural practice:

- Use of qualitative knowledge: designers and researchers claimed to make frequent use of such information. We believe that this knowedge can be adopted to constraint simulation models, reducing the scope of analysis and the time of response.
- Quantitative knowledge: computer simulation requires technical knowledge. Such information might be unfamiliar to most designers. Therefore, we believe that architect-researchers may be more able to use simulation tools within design as they have access to a wider range of knowledge. The use of BPS by most architects requires profound changes in the architectural education. Simulation tools can certainly be a part of the architectural design education, which would benefit the professional practice of future architects. In order to start this process, the development of simulation methods that are more adequate to architects is crucial.
- Design information: simulation procedures can also support early design decisions. In order to do that, the identification of which available information is more or less relevant to be used in the model is necessary. Even though the use of simulation was not directly mentioned in the survey question, the respondents could identify relevant design information that can be suitable to be used as inputs in the model for each type of assessment considered.

The survey presented here consists of a first approach towards the use of simulation tools within the architectural design process. Other methods and procedures should be further applied in order to deepen and investigate the concepts derived from this research.

CONCLUSIONS

We described in this paper the results of a survey approaching the architectural design practice. The questionnaire was hosted online, and its links were forwarded to specialized discussion lists. Three professional categories were surveyed. The total sample consists of 51 architect-designers, 55 architect-researchers and 24 design consultants.

The survey was divided in three sections with different approaches. The questionnaire was developed to allow the collection of the following information:

- General information: location, climate and professional information of each sample.
- Methods: in which phases and how each category tackles design decisions.
- Information: which design information is relevant to tackle design decisions.

The results of each category allow the identification of similarities and differences among the three samples.

Results show that most designers are from South America (66%), are not post-graduated (70%), use design guidelines (57%) and solar simulation tools (55%). The majority of the sample has up to five years of design experience (57%) and is involved frequently with design activities (67%).

Nearly all researchers surveyed are from South America (87%). Most of them use design guidelines (65%) and have concluded at least one post graduate study in the field (58%). Researchers claimed to use more simulation tools compared to designers. The background of consultants is fairly diversified. Most of them are post graduated (67%) and use simulation tools (95%).

Interestingly, the two tools preferred by consultants and researchers (EnergyPlus and ECOTECT) are considerably different in terms of robustness and usability. Other friendly tools, such as DesignBuilder and IES-VE are also fairly popular among consultants (each tool selected by 25%).

Although the three categories tackle most design decisions in similar design stages, some differences were identified. Part of the sample of consultants approaches the definitions of building form and volume in mid design stages, in contrast to designers and researchers. Besides that, consultants tackle some technical definitions (glazing properties and external colors) earlier than other categories.

Regarding the methods and information used to support design decisions, results indicate that architects and researchers proceed in a fairly similar way. However, researchers claimed to use more qualitative and quantitative procedures in comparison to architects. As expected, the use of quantitative information is higher among consultants.

Within the scope of decisions investigated, we observe that designers and researchers analyze air flows based solely on qualitative criteria/information. Although both categories claimed to adopt more than one wind direction, the analysis of different scenarios would be impossible without using at least basic knowledge about pressure coefficients.

The results of the third section of the survey allowed the identification of the most relevant design information to tackle specific decisions.

The design of shading devices is strongly related to the definition of opening features (size, orientation and location) and form (zoning and orientation). Site features and volumetric definition also pointed by designers and research as relevant information.

The definitions of walls/roofs properties are quite dissociated from other decisions. In practice, the selection of constructions can be based on the properties of materials. The most relevant design information is the volumetric definition and the orientation and size of openings.

In order to take decisions to maximize or control air flows, the most relevant information was the form (zoning and orientation) and openings features (orientation, size and location). Information such as 2D form is more adequate to qualitative support. Simulation models would require volumetric definitions or even site features. Both definitions were considered very relevant to designers and researchers. The internal layout was considered relevant by all categories as it affects internal air flows.

The survey is intended to enhance our understanding about current architectural practice. In general, we observe that consultants and designers are in extreme situations in terms having the technical expertise and understanding other aspects of design that are not quantifiable. We believe that architect-researchers combine features from both other categories, which can facilitate the use of BPS as conceptual tools in design education. In the long term, this could certainly benefit the professional practice of future architects.

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REFERENCES

Attia, S., L. Beltrán, A. D. Herde e J. Hensen. "Architect Friendly": a comparison between ten different building performance simulation tools. Building Simulation. Glasgow, Scotland 2009.

Bay, J.-H. Cognitive Biases in Design: The case of tropical architecture. (PhD). TU Delft, Delft, Netherlands, 2001.

E-Surveyspro. e-surveyspro. www.esurveyspro.com. Acessed in Jul-2010. 2010.

Mahdavi, A., S. Feurer, A. Redlein e G. Suter. An inquiry into the building performance simulation toolsusage by architects in Austria. Building Simulation. Eindhoven, The Netherlands 2003.

Morbitzer, C. Towards the integration of simulation into the building design process. (PhD). Department of Mechanical Engineering, University of Strathclyde, 2003.

Pedrini, A. e S. Szokolay. The architects approach to the project of energy efficient office buildings in warm climate and the importance of design methods. Building Simulation. Montreal, Canada 2005.

Venâncio, R. e A. Pedrini. The influence of design decisions on energy consumption and thermal performance: the case of UFRN Campus, Brazil. Building Simulation. Glasgow, Scotland 2009.