Integration of sustainability in the design process of contemporary architectural practice

Maureen Trebilcock[1,2], Brian Ford[1] and Robin Wilson[1]

[1]School of the Built Environment, University of Nottingham, Nottingham, UK
[2]Departamento Diseño y Teoría de la Arquitectura, Universidad del Bío-Bío, Concepción, Chile

ABSTRACT: This paper explores the integration of sustainability in the architectural design process with particular emphasis on the role of design-assisting tools. The methodology was based on five case studies of contemporary architectural practices in Europe that are considered to be leaders in the field of sustainable design: Edward Cullinan, Michael Hopkins and Feiden Clegg Bradsley in the UK; Mario Cucinella in Italy; and Behnisch, Behnisch and Partner in Germany. A specific non-domestic sustainable building designed by each practice was chosen as an embedded unit of analysis. The data collection strategies included interviews with architects, engineers and clients; as well as compilation of graphic information including drawings and reports; and observations.
The conclusions establish that early stages of the design process are based on knowledge and experience of the architects and engineers, usually embedded in the form of architectural precedents. Design-assisting tools play very limited role at early stages, and an important but restricted role during design development, mostly as checking tools and to inform some minor architectural decisions. In addition, they sometimes become a tool of communication and client persuasion. The role of these tools in the decision-making process increases enormously when there is a high risk perceived in the project.

Keywords: design process, sustainable architecture, design-assisting tools, interdisciplinary work.

1. INTRODUCTION

There is increased awareness amongst architects of the urgent need to integrate sustainability in their projects, driven by the growing awareness of the impact mankind is having on the planet. Integration is a key aspect of sustainable architecture that implies shifting from the modern western pursuit of reductionism to a holistic view of interrelatedness and entirety throughout the design process. Understanding the design process with respect to the integration of sustainability demands that the uniqueness and complexity of the process is acknowledged and that the interplay between the role of the technical and the social skills brought to bear by different players within the design team is studied. The technical dimension is defined in this study as the use of design-assisting tools and methods; while the social dimension is defined as interdisciplinary collaborative work.

Researchers have acknowledged the importance of design-assisting tools to help facilitate the integration of sustainability in the design process and have focused on the development of these tools, particularly for early stages of the design process when most of the crucial design decisions are made. This top-down approach of developing tools, methods and guidelines has dominated research in the field.

But, what actually occurs in practice? How do architects integrate sustainability in the design process? What is the role of design-assisting tools in contemporary architectural practice? The predominance of the top-down approach to research in the field seems to have left a gap between research and practice that might be filled by a bottom-up approach of learning from practice.

This paper explores the role of design-assisting tools in the integration of sustainability in the design process from a bottom-up approach to research. It is based on a naturalistic system of inquiry, in which the basic ontological premise recognises that there are multiple, socially constructed realities; in this case it recognises the uniqueness and complexity of the design process. The naturalistic approach also recognises that it is neither possible nor necessarily desirable to establish a value-free objectivity; so it is important to acknowledge the role that interpretation has played in reporting the findings of this study [1].

2. METHODOLOGY

2.1 Case Study Theory Building

The research method of case study theory building is appropriate for the aims of this project because it is a bottom up approach that maintains that the specific of data produce the generalisations of theory [2]. This method is particularly useful to investigate a contemporary phenomenon within its real-life context [3]. The case studies are contemporary architectural practices and the embedded units of analysis are the design processes giving rise to sustainable buildings designed by each practice.

2.2 Selection of cases

The first stage of the selection of cases consisted of screening seventeen contemporary architectural practices in Europe that are considered by the architectural media as leaders in sustainable design. From those seventeen cases, five cases were chosen according to accessibility criteria. After a first interview with one of the architects, one recent non-domestic sustainable building designed by the practice was selected as an embedded unit of analysis.

2.3 Data collection

Data collection was based on triangulation: using multiple sources of information, rich in context. It included semi-structured interviews with different members of the design team; essentially architects, engineers and clients. It also included compilation of various types of documents that recorded the design process: architectural drawings, sketches, reports, multimedia presentations, photographs, articles in journals, etc. Finally, it included observations of the buildings.

3. CASE STUDIES

3.1 Cullinan and Downland Gridshell

Edward Cullinan Architects is one of the leading British practices, based in London. Their work is recognised for its collective spirit; its relation to landscape; its fascination with the construction process and the expressionism of materials. They have designed significant sustainable buildings in the UK, such as Archeolink Visitors Centre; the Faculty of Mathematics at Cambridge and the Millennium School and Health Centre at Greenwich.

Downland Gridshell is one of the most relevant sustainable buildings designed by the practice during the last few years. It is part of the Weald and Downland Museum in West Sussex, UK, and it houses a workshop for restoring timber frame buildings and an artefact store. The building was designed between 1996 and 2002 by a team led by Cullinan and the engineers Buro Happold (Fig. 1).

Figure 1: Downland Gridshell

Most of the sustainable agenda of the project focused on the design of an efficient structure that would make an economic use of materials; and on the procurement of local and sustainable building materials. The design of the first double-layered timber gridshell in the UK implied a high associated risk for the design team. The design process was mainly driven by the structural design of the gridshell that required extensive use of design-assisting tools to diminish the risk.

3.2 Hopkins and the Business School

Hopkins Architects is an internationally recognised architectural practice, based in London, UK. Their projects are based on a principle of truth to materials and expression of structure that results in logical designs; or what Davies calls 'environmental rationalism' [4]. Some of their sustainable buildings include the Inland Revenue in Nottingham; Jubilee Campus at Nottingham University; and Porticullis House in London.

The Business School is an extension of the award-winning Jubilee Campus of Nottingham University. It was designed between 2001 and 2004 by a team led by Hopkins and the engineers Arup (Fig. 2).

Figure 2: Business School

The sustainable agenda of the building tried to replicate the first phase of Jubilee, focusing on mixed mode ventilation, optimisation of daylight and provision of low-energy efficient equipment.

The idea of replicating the first phase dominated the whole design process, where the underlying concepts were used as a precedent and a model to develop. In contrast to Downland Gridshell, there is little evidence that design tools played an important role in the decision-making process.

3.3 Feilden Clegg Bradley and the National Trust

Feilden Clegg Bradley Architects have a reputation of pioneers in sustainable architecture in the UK. They place climate change very high on the practice's concerns, so their projects tend to focus on reducing CO_2 emissions within a holistic sustainable agenda. Some of their well-known sustainable

buildings are the BRE Environmental Building and Greenpeace Headquarters.

The National Trust Headquarters in Swindon, UK, is due to become an exemplar building in terms of low CO_2 emissions and one of the best day lit and naturally ventilated office buildings in the UK. FCBA and Max Fordham engineers led the design team. The design process started in 2002 and the building was handed over in 2005 (Fig. 3).

Figure 3: National Trust Headquarters

The sustainable agenda behind the building was very comprehensive, covering aspects from CO_2 emissions to transport. The main features were daylight and natural ventilation that concentrated most of the team's attention. The deep plan two-storey scheme represented an unusual solution for an office building, but it responded to the existing nineteenth century industrial buildings on the site and it provided natural light and ventilation via the roof.

The performance of the proposal was analysed throughout the design process using different tools and focusing on daylight, solar penetration and natural ventilation.

3.4 Cucinella and Hines

Mario Cucinella Architects is a relatively young practice based in Bologna, Italy. They claim to have an integrated approach to design where sustainability and low energy design are high on the agenda. They have designed several sustainable buildings such as the iGuzzini offices and the City Hall of Bologna.

The Hines office building was the result of an international competition launched in 2001 to renovate a former Post Office complex in Milan, Italy. The team comprised by Cucinella and Arup won the competition and designed this building that was handed over in 2004. It is unusual that a speculative commercial building would have a sustainable agenda, but the developers Hines were interested in including some sustainable features such as chilled beams; a double skin façade to control solar gains and a climatically sheltered courtyard (Fig. 4).

Figure 4: Hines building

The architects performed solar analysis of the existing buildings at the beginning of the design process and an energy assessment at the end of the process. However, the evidence suggests that the integration of sustainability in the design process of this building was mostly guided by knowledge and experience, rather than on the use of design-assisting tools.

3.5 Behnisch and Nord/LB

Behnisch, Behnisch and Partner is a practice of broad international reputation, based in Stuttgart, Germany. It is committed to innovative architecture and sustainability is very high on their agenda. They have designed some internationally recognised sustainable buildings, such as the Genzyme Centre in Cambridge, US; and the Institute for Forestry and Nature Research in Wageningen, Netherlands.

The Nord/LB Headquarters in Hanover, Germany was designed between 1996 and 2004 by a team led by Behnisch and Transsolar energy consultants. The building was also the result of an international competition that sighted to bring together seventeen separate branches of the bank on one site (Fig. 5).

Figure 5: Nord/LB Headquarters

The sustainable agenda behind the building focused on energy saving strategies that resulted in low CO_2 emissions. They included natural ventilation, daylighting and component cooling. The design process required extensive use of design-assisting tools to inform design-decisions, covering mainly daylight analysis, thermal simulations and computational fluid dynamics.

4. THE ROLE OF DESIGN-ASSISTING TOOLS

4.1 Non-interactive Tools

Sustainable design guidelines, checklists and element catalogues might be referred as 'non-interactive tools' because they assist design decisions but they do not allow the user to take an active approach. While design guidelines take the form of a declaration of intent that establish specific objectives and even appropriate solutions (e.g. RIBA Green Guide to the Architect's Job Book) [5]; checklists are more practical and intend to structure activities (e.g. BREEAM checklists) [6]; and element catalogues provide information to compare different building materials and products (e.g. Green Guide to Specification) [7].

Despite the fact that there are dozens of sustainable design guides available in books and manuals, the evidence suggests that they had no role in the design processes of the case studies. The sustainable agendas of the projects were developed according to the architects' and client's definitions of sustainable architecture and on the different values that they gave to different aspects of sustainability.

In case of Downland Gridshell the value of sustainability was centred on the relationship with place and landscape and the agenda was focused on local and sustainable materials. For the National Trust HQ it was centred on low CO_2 emissions and the agenda was focused on low energy strategies and energy generation. The agendas were not always evident from the beginning of the design process; rather they were developed in conjunction with the project, as a result of the dialogue between the architects and clients. Sometimes the sustainable agendas were not even declared, but they were evident in the process and the result.

In the case of the National Trust HQ, the architects used the Green Guide to Specification as an element catalogue to select sustainable materials and products. The tool was considered to guide one-line decisions (material specification) rather than as a comprehensive design tool. In the same case, the architects in conjunction with the engineers developed their own checklist that they named 'the matrix of sustainability'. The matrix was the result of the design team's sustainable agenda and it helped to guide the clients in setting specific targets for the project. It worked as a graphic representation of targets that helped to guide the clients on where to invest their money. Rather than a design tool, it could be considered as a management tool.

It is interesting to note that the only checklist that played any role in the cases studied was a self-made one, rather than an off-the-shelf. This fact proves the statement by Williamson, Radford and Bennetts who declare that since sustainable architecture is a cultural construction, no checklist could be objective or complete, because they cannot cope with the complexities and uniqueness of the design process [8]. Guidelines and checklists are inherent to the designer's values and definitions of sustainable architecture and are also tailored by the client's own values and expectations.

However, it is important to note that this study selected recognised experts in the field, so there is probably not much in off-the-shelf guidelines and checklists that the experts do not already know.

4.2 Analysis Tools

Analysis tools enable the user to take an active role in analysing and evaluating design solutions. They can be either computer-based (e.g. building performance simulation programs) or physical tools (e.g. artificial sky). Currently, there are hundreds of simulation programs of different levels of sophistication and developed to serve different purposes.

The evidence gathered in this study suggests that analysis tools had an important but limited role in integrating sustainability in the design process. They were used in some cases to assist design decisions, but in most cases the architects and engineers claimed that what actually drove the design process were knowledge and experience.

Interestingly, the role that analysis tools played in assisting design decisions became more essential in those cases where there was high-perceived risk. They were used to predict performance in order to diminish risk. This was the case of the naturally ventilated office buildings, such as the National Trust and the Nord/LB that required extensive analysis to control the perceived risk of overheating. On the other hand, the structural engineers of Downland Gridshell performed extensive analysis to control the risk of structural failure. The non-naturally ventilated buildings (Business School and Hines) required much simpler analysis. The evidence suggests that the use of design tools is not necessarily inherent to every project with a sustainable agenda, but it rather follows the purpose of controlling a perceived risk.

In all cases, early stages of the process (i.e. the generation of the first idea) were driven by knowledge and experience of both architects and engineers who started working as a team from the beginning of the process, and long before in some cases. Knowledge and experience were embedded in the form of rules of thumb and building precedents, which were usually the designers' own previous projects. Only in the case of Hines building the architects claim that the process started with a solar analysis with Ecotect, mostly because it was a restoration project where all buildings existed, so the shapes, orientation and layout of the buildings was already determined. In all other cases, the 'tools' that determined the basic shape, orientation and size of the buildings were rules of thumb and precedents.

After the basic layout of the buildings was determined, the designers used some simple tools to refine the design and to decide particular aspects of

the proposal. For the National Trust HQ, the architects used Ecotect to model a portion of the building to determine daylight factors, which informed aspects such as the orientation of the mezzanines in relation to the rooflights. In the case of Downland Gridshell, the architects made physical models and the engineers made computer models to refine the shape of the gridshell. In the case of Nord/LB, the engineers modelled a section of the double glazed façade to determine its depth, size of window openings and the specification of the glazing. In all these case, the tools were used to refine the design after the main ideas were already established.

Table 1 summarises the analysis tools that were used in each unit of analysis; indicating at which stage of the design process they were used; which member of the design team performed the analysis; and the use of the tool.

Table 1: Use of Analysis Tools

Analysis Tools				
unit	**type**	**stage**	**member**	**use**
Downland Gridshell	physical models	OP/SD	arch+eng	form finding
	computer models	SD	engineer	form finding and dimension of structure
	prototypes	DD	carpenter	construction tests
Business School	Hevacomp	DD	engineer	size of plant
National Trust HQ	Ecotect	OP	architect	daylight factors of typical area
	artificial sky	SD	engineer	solar penetration daylight factors
	TAS	SD	engineer	thermal simulation
Hines building	Ecotect	OP	architect	solar radiation and shading
	Giacomelli	after DS	architect	winter energy consumption
	method Santamouris	after DS	architect	summer energy consumption
Nord/LB	Radiance	SD	engineer	daylight simulation
	TRNSYS	SD	engineer	thermal simulation
	FIDAP	SD	engineer	air flow of double skin facades/halls
	physical model	SD	engineer	air flow visualisation
	TRNSPILE	SD	engineer	size of ground heat exchanger and component cooling

Key:
OP: Outline proposal (RIBA, UK)/ projetto preliminare (Italy)
SD: Scheme design (RIBA, UK)/ design development (Germany)
after DS: after completion of design stages

For later stages of the design process, the tools became more sophisticated and were used mostly to check the proposals and to make minor refinements. Generally, engineers consider that this is an appropriate way of proceeding, because complex modelling is very time consuming and early stages of the design process occur very fast. They also prefer to perform simulations when there are a limited number of variables to test, i.e. at late stages of the process when the major design decisions have been made; rather than having a large number of options, i.e. at early stages. On the other hand, they believe that their experience is usually sufficient to ensure that the performance of the proposal would satisfy their expectations, but they still need to test it after design completion, particularly when there is a perceived risk involved. Mainly, they need to prove to the clients that the building will perform adequately.

The case studies put forward the fact that it was the engineers who performed most of the analysis, using mainly sophisticated tools. In most cases, the design team indicated that they prefer to have a clear demarcation of roles were the architects were leaders of the design team and the engineers had a supportive role of advice and analysis. This clear demarcation of roles is complemented with close collaborative teamwork, based on long standing pre-existing professional relationships that are helping to guide the design process. The evidence suggests that the current tendency on the use of tools is based on specialisation (engineers using sophisticated tools) complemented with effective teamwork, rather than on user-friendliness (architects using simple tools in-house).

It is important to note that in all cases the architects have chosen, as part of the design team, an engineering practice that has an expertise in sustainable design, such as Arup, Buro Happold, Transsolar and Max Fordham. These engineers have vast experience and skills in the use of analysis tools, which reinforces the tendency on specialisation and teamwork.

However, in two cases the architects performed simple analysis at early stages that informed some specific early design decisions. In both cases it was dependant on having a young architect in the office who was able to use Ecotect to perform daylighting analysis. This fact suggests that the tendency could shift towards non-specialist analysis with user-friendly tools if there are more architects trained in this area. Nevertheless, it is important to note that daylighting analysis is more accessible and easy to manipulate than thermal or airflow analysis, which could still require the assistance of specialists.

The management of tools is also probably dependant on the tradition of the architectural practice of organising interdisciplinary teamwork. While most cases seem to adhere to the tradition of a practice of 'purely architects' that are supported by the specialists, some appear more open to including analysis and simulation as part of their job. Younger practices that have embraced the sustainability agenda from their early days seem to be more receptive to adjust their design process to latest tools, including the new generation of generative or 'intelligent' tools.

Interestingly, the evidence also suggests that in most cases the analysis results were also used to communicate the sustainable design strategies to the client, funding bodies, competition judges, etc. In a way, they were used to persuade these bodies to approve the proposals, undertaking a role of communication, representation and persuasion that complemented their main analytical role. Even more, in some cases it appears that analytical diagrams have followed the aim of persuading client bodies, rather than truly informing design decisions. They have helped to show the clients that the project has not only embraced sustainability concepts, but the concepts have also been analysed and evaluated.

This strategy helps to present the design process as a 'scientific' process, which can be welcomed by clients bodies; even if the true nature of the design process is not necessarily scientific; i.e. design decisions have not been made strictly according to the analysis results, but as a combination of intuition, creativity, designer's values, etc.

Therefore, while complex and challenging design proposals require extensive use of design-assisting tools to manage risk; simpler low-risk proposals still require the tools to show the clients a 'scientific approach' to the integration of sustainable principles in the design process.

4.3 Methods of Environmental Assessment

The methods of environmental assessment can be classified in two groups: quantitative and qualitative methods [9]. The quantitative methods use a life cycle approach with quantitative input and output data based on flows of energy and matter (e.g. Envest, EcoQuantum) Qualitative methods are based on the auditing of buildings, giving a score to different parameters, where some parameters are quantitative and others are based on criteria. They are used as rating schemes that compare the building against an archetype building (e.g. BREEAM in UK, LEED in US).

Only two cases underwent formal processes of assessment: Downland Gridshell underwent a life cycle assessment with Envest and the National Trust had an 'Excellent' BREEAM rating. The Business School and the Hines building used qualitative methods - BREEAM and LEED respectively - as checklists when developing the sustainable agendas of the buildings.

The information gathered, including the responses from the interviews, indicate that the methods had a limited role in the design process. When they were used as checklists they provided a general reference on which sustainability aspects to consider that had a limited effect on design decisions. When they were used as an assessment and certification method, the evaluation was done after design stage, so they had no impact on design decisions.

Nevertheless, in all cases in the UK the architects were interested in having a BREEAM certificate either because it was a good marketing strategy, or because it was a way of ensuring quality and sustainability standards after the project was submitted to tender. The barriers for having a certificate were budget restraints and lack of adaptability of the method to the building type, e.g. when Downland Gridshell was designed in 1996, it did not fit with any building type of BREEAM (now 'bespoke' BREEAM should overcome this barrier).

The cases outside the UK were not particularly interested in having an environmental assessment. Apart from the fact that there is no local method available in those countries, the architects felt that there is no need for having a certificate. Either building regulations or the design team and client were the drivers of sustainability of the projects. The evidence suggests that the use of methods of environmental assessment is dependant on the cultural framework of the project.

5. CONCLUSIONS

A case study research approach allowed to cross-relate data of different nature that made possible an understanding of the use of design-assisting tools in the integration of sustainability in the design process that is rich in detail.

The evidence suggests that the integration of sustainability at early stages of the design process is guided by knowledge and experience in the form of precedents; while later stages of the process are supported by analysis tools; from simple methods to sophisticated tools. The current tendency is that some architects would use simple tools to perform simple analysis, such as daylighting, that would inform minor design decisions. The use of tools at later stages of the design process is based on specialisation and effective teamwork, rather than on user-friendly tools in-house the architectural practice. Sophisticated tools would inform minor decisions and would generally check and prove design strategies.

The role of the tools becomes more important in assisting design decisions when there is higher perceived risk involved in the project. In low-risks projects the tools also assume a role of communication of sustainable principles and persuasion of client bodies.

ACKNOWLEDGEMENTS

This paper is a result of a PhD project that has been funded by the Alban Programme of the European Commission and MECESUP-Universidad del Bío-Bío, Chile.

REFERENCES

[1] L. Groat and D. Wang, Architectural Research Methods, John Wiley and Sons, New York, 2002.
[2] K. Eisenhardt, Building theories from case study research, Academy of Management Review, 1989, 14(4), 532-550.
[3] R. Yin, Case Study Research: design and methods, 3rd ed, Sage Publications, Thousand Oaks-California, 2003.
[4] C. Davies, Hopkins2: the works of Michael Hopkins and partners, Phaidon press, London, 2001.
[5] S. Halliday, Green Guide to the Architect's Job Book, RIBA Publications, London, 2000.
[6] www.breeam.org
[7] J. Anderson, D. Shiers and M. Sinclair, The Green Guide to Specification: an environmental profiling system for building materials and components, 3rd ed, Blackwell science, Oxford, 2002.
[8] T. Williamson, A. Radford and H. Bennetts, Understanding Sustainable Architecture, Spon Press, London, 2003.
[9] A. Forsberg and F. von Malmborg, Tools for environmental assessment of the built environment, 2004, 39(2), 223-228.