

# **The Role of Analytical Tools in the Design Process of Sustainable Buildings**

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**ABSTRACT:** The technical challenges of sustainable design and the advances in the development of analytical tools have stressed the role of quantifiable analysis in the design process. However, architectural practices face the difficulty of integrating analysis with traditional design procedures that are mostly based on intuition. This paper explores the role that analytical tools play in the design process, based on five case studies of contemporary architectural practices in Europe that are considered to be pioneers in the field of sustainable design. A specific non-domestic building designed by each practice was chosen as an embedded unit of analysis with the intention of mapping its design process. 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 case studies suggest that the role of analytical tools is counterbalanced by intuitive elements within a social framework of interdisciplinary teamwork. It is stressed by the degree of complexity, innovation and risk of the project and by the level of expertise of the design team. In addition, it is usually complemented by a role of communication and persuasion of client bodies that has proved to be as important as their main analytical role.

**Keywords:** tools, sustainable design, analysis, design process

## **1. INTRODUCTION**

The technical challenges of environmental sustainability and the advances in the development of analytical tools have stressed the role of the quantifiable analytical process in architectural design. This process refers particularly to the use of analytical tools to guide, analyse and evaluate sustainable design decisions. Researchers have acknowledged the importance of analytical tools in the design process and have developed tools of different levels of sophistication and developed to serve different purposes. However, architectural

practices face the difficulty of integrating analysis with traditional design procedures that are mostly based on intuition.

This paper explores the role of analytical tools in the integration of environmental sustainability issues 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

The methodology was based on the qualitative research tradition of case studies, which proved to be valuable in retaining the holistic and meaningful characteristics of the design process as a real-life event. The case studies are drawn from the work of five contemporary architectural practices in Europe that are considered by the architectural media as pioneers and leaders in environmentally sustainable design. Each case study contains an embedded unit of analysis consisting in the design process of a sustainable building designed by each practice: Feilden Clegg Bradley Architects and Heelis (UK); Hopkins Architects and The Business School of the University of Nottingham (UK); Edward Cullinan Architects and Downland Gridshell (UK); Mario Cucinella Architects and Hines building (UK); and Behnisch Architekten and NORD/LB (Germany) [2].

The design process of each building was mapped using multiple sources of information, rich in context. It included semi-structured interviews with architects, engineers and clients. It also included compilation of various types of documents that recorded the design process (architectural drawings, sketches, reports, multimedia presentations, etc.) and observations of the buildings.

## 3. THE ANALYTICAL PROCESS

The evidence gathered from the case studies suggests that analytical tools had an important but limited role in the integration of environmental sustainability issues in the design process. They were used to assist design decisions, but in all cases the architects and engineers claimed that what

actually drove the design process was knowledge and experience. Only in one case do the architects claim that the process started with a solar analysis, mostly because it was a refurbishment project where all buildings existed, so the shapes, orientation and layout of the buildings was already determined. In all other cases, the basic shape, orientation and size of the buildings were determined by knowledge and experience of the design team.

Based on the findings, this paper proposes that the integration of sustainability issues in architectural design occurs as two complementary processes of intuition and analysis within a framework of social interaction between the members of the design team. The intuitive process is based on knowledge and experience of the design team and guides early and fundamental design decisions. The analytical process is dominant at late stages of the process and is guided by the use of analytical tools to inform and check design decisions.

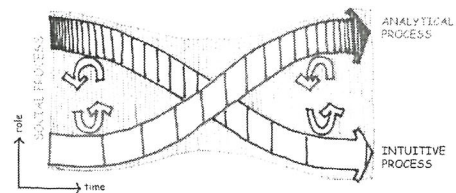


Figure 1: diagram of the analytical and intuitive processes

Architects prefer to rely on intuition at early stages of the design process because at these stages design decisions occur very fast, leaving no time for analysis. If the architects rely on the engineers to do the analysis there is also a 'time gap' that hinders the speed of the process.

At middle stages of the process, after the basic form and layout of the buildings were determined, the designers undertook some simple analysis to determine particular aspects of the proposal. They used either simple tools to model the whole building or complex tools to model a portion of the

building in order to refine the design after the main ideas were already established.

At later stages of the design process the tools became more sophisticated and were used primarily 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 complex 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.

What underpins this approach is a belief that designers' experience is usually sufficient to ensure that the performance of the proposal would satisfy their expectations, but a recognition that 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. These opinions suggest that in addition to the whole team following the model of intuition and analysis, individual members also exhibit it.

Evidently, the use of analytical tools has to be supported by knowledge and experience. The implications of this fact are double folded. On one hand, the proliferation of user-friendly tools could risk the validity of the results if they are used by people lacking the necessary knowledge and experience in sustainable design. On the other hand, even at an expert level, there is sometimes a gap between the language of the architects and the language of the engineers that can only be overcome by effective dialogue and teamwork. Therefore, success in the integration of analytical tools in the design process depends essentially on competence of the design team as well as on close interdisciplinary teamwork.

The process works in both ways: while knowledge and experience support the use

of analysis tools, the analytical process helps to build the knowledge and skills of the designers.

### 3.1 Trends in tools management

The case studies also indicate that it was the engineers who performed most of the analysis, using mainly sophisticated tools. Most cases show a tendency for the use of tools based on specialisation (engineers using sophisticated tools) complemented with effective teamwork, rather than on user-friendliness (architects using simple tools in-house). Whether this trend will dominate the future or not is difficult to infer from the case studies because all the engineering practices have vast experience and skills in the use of analysis tools, which reinforces the tendency for specialisation and teamwork. However, one of the cases underlined the fact that the availability of expert engineers on a local level is crucial for the predominance of this trend.

On the other hand, in two cases the architects performed simple daylighting analysis using Ecotect at early stages, which informed some specific middle stage design decisions. This fact suggests that the tendency could shift towards non-specialist analysis with user-friendly tools if there are more architects trained in sustainable design and particularly in daylighting analysis, which is more accessible and easy to manipulate than thermal or airflow analysis that could still require the assistance of specialists. The increasing number of user-friendly tools with graphical interface available in the market and the recent changes in architectural education where young architects are becoming better trained in environmental analysis might also support this trend.

It is possible too that the management of tools is dependent on the presence of a tradition within the architectural practice. While most cases seem to adhere to the tradition of a practice of 'purely architects' that are supported by 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 adjusting their design process to latest tools, including the new generation of generative tools.

### 3.2 Complexity, innovation and risk

The role that analytic tools played in assisting design decisions became more essential in those cases that were more complex, innovative and particularly where there was high-perceived risk. They were used to predict performance in order to diminish risk.

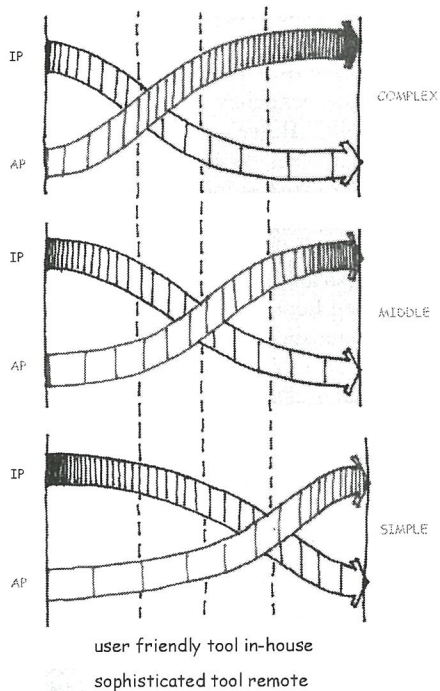


Figure 2: variations of the analytical and intuitive processes depending on the level of complexity of the project

The diagram in Figure 2 presents three variations of the analytical and intuitive processes according to the level of complexity, innovation and technical risk of the project. Although the intuitive process plays the most important role at early stages

of the design process in all cases, the role that the analytical process plays varies depending on the degree of complexity, innovation and risk. Complex and innovative projects that involve high risks require extensive use of analytic tools to inform a whole variety of design decisions because the designer's experience might not be sufficient to guide design decisions. Simple projects that do not involve high technical risk do not require extensive analysis to inform design decisions.

However, complexity and innovation are relative concepts that depend on the level of expertise of the design team. A project that might seem simple for an expert team, might not be simple for a novice team that might be forced to rely on more analysis to support ideas that an expert team can easily support by experience.

Complexity and innovation are major design issues that cross over all dimensions of the design process. Dealing with them not only requires extensive use of analysis tools, but also interdisciplinary teamwork from early stages of the design process and the generation of knowledge from previous experience.

### 3.3 Representation, communication and persuasion

The evidence 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 representation, communication and persuasion that complemented their main analytical role. Further, in some cases it appears that the diagrams that resulted from the use of analytical tools have served as a means for 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 'scientific', which allays the concern of client 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, rather as a combination of knowledge, experience *and* analysis.

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. CLOSING THE LOOP BETWEEN INTUITION AND ANALYSIS

Based on the case study evidence that proved that fundamental design decisions are guided by knowledge and experience, instead of promoting the use of analytical tools at early stages of the process, research and practice should concentrate on shifting the stage of analysis to fill the gaps that exist between consecutive architectural projects in order to help build solid knowledge. This analysis takes the form of post-occupancy evaluation (POE); a valuable method of learning from experience.

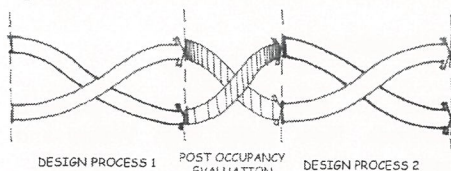


Figure 3: POE and the continuous design process

Figure 3 proposes a diagrammatic representation of the continuous design process that is reached by closing the loop between the design processes of sequential projects by a stage of POE. This linking process feeds the knowledge of the designers and allows them to start the next

project at a different – improved – level of knowledge and expertise that creates a solid base for the intuitive process. In addition, the analytical process is also reinforced by the inclusion of this linking stage because it allows designers to check and calibrate their design-assisting tools against real measurements.

The proposal of the continuous design process is based on the fact that in the same way that the stages of the design process are not well defined (detail design stage goes into construction stage, etc.); the boundaries between subsequent building projects are blurred within professional practice. This idea was underlying in all the case studies, where architects see their current projects as continuations of previous architectural projects and as precedents of future projects.

To date most of the case studies had no post-occupancy evaluation (POE). The designers received some informal feedback from the buildings' users that gave them partial information on the performance of some elements or strategies, but not enough to actually build solid knowledge. This situation is endemic and not only applies to the case study buildings, but also to most of the buildings that they have designed, as well as to their 'external precedents'.

The importance of closing the loop of the design process by having POE is partly based on the fact that predicted performance can be over three times better than real performance [3].

Most of the case studies available in books and sustainable design guidelines lack information on this fundamental last stage of the process. The risk created by this omission lies in the possibilities that designers replicate strategies and systems that have failed in previous projects. Considering the key role that precedents play in guiding design decisions throughout the design process and fundamentally at early stages, it is essential that sustainable design guidelines provide complete and truthful information on the case studies. Unfortunately, this is not always the case

and architects sometimes receive shallow and partial information that could easily misguide them.

There is a point of interaction at the POE stage between the intuitive and analytical processes, as qualitative information can help to provide benchmarks for the analytical process, while quantitative information can help to build knowledge for the intuitive process. This point of interaction is very dynamic as quantitative and qualitative information can be used for a wide variety of purposes, closing the loop between different design processes, as well as between intuitive and analytical dimensions, as shown in Figure 4.

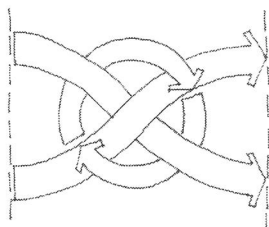


Figure 4: the closed loop at POE stage

Quantitative and qualitative information complement each other to give a comprehensive source of knowledge. The data can inform a wide variety of disciplines as it can be looked at from different perspectives: client, users, M&E engineer, architect, facilities manager, etc. It can help facilities managers to find methods to operate the building more effectively; it can help users to understand how the building works; it can help the design team to evaluate a particular strategy in order to make the necessary amendments and to update their knowledge for future projects.

## 5. CONCLUSIONS

Analytical tools play an important role in the integration of environmental sustainability issues in the design process, but limited mostly to middle towards late

stages of the process, when they are used for refining and checking design decisions.

The analytical process is complemented by an intuitive process based on knowledge and experience of the members of the design team, which is dominant at early stages of the process to define the shape and layout of the building. These two complementary processes work in both ways: while knowledge and experience support the use of analytical tools, the analytical process helps to build the knowledge and skills of the designers.

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

The findings highlight the importance of POE to close loop between intuition and analysis and between consecutive design processes. This linking stage helps to feed the knowledge of the designers and to allow them to start the next project at a different – improved – level of knowledge and expertise that creates a solid base for the intuitive process. It also reinforces the analytical process because it allows designers to check and calibrate their analytical tools against real measurements.

## 6. REFERENCES

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