

Integrated Design Process: From analysis/synthesis to conjecture/analysis

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ABSTRACT: The concept of Integrated Design Process found in current literature is based on an understanding of the design process as Analysis/Synthesis (A/S); where the problem is broken down into sub-problems and individual problems, reaching individual solutions and sub-solutions until achieving the overall solution. This paper proposes that the integrated design process in the practice of sustainable design is closer to a Conjecture/Analysis (C/A) model that suggests that designers would propose an idea (or conjecture) before attempting to do any analysis. In addition, it proposes that both the architect and the engineers would proceed in a similar manner, sharing the character of designer. The research methodology was based on case studies of contemporary architectural practices in Europe and South America that are pioneers in sustainable design. The design process of a sustainable building designed by each practice was mapped using interviews with architects, engineers and clients; as well as analysis of graphic information and documents.

Keywords: Integrated Design Process, sustainable design, energy efficiency

MODELS OF THE DESIGN PROCESS

In its most basic form, to elaborate a model of the design process means to map a route through the process from beginning to end. The idea is to identify the actions that the designer makes in order to achieve a desired solution. A generalized map of the design process that emerged from the first generation of design methodologists [1, 2] suggests that activities such as analysis, synthesis and evaluation occur in sequence. Analysis involves breaking down the problem into fragments to solve each fragment separately; synthesis is characterised by an attempt to create a response for the problem; and evaluation involves the critical appraisal of suggested solutions against the objectives identified in the analysis phase. This model has been identified as Analysis/Synthesis (A/S) and is influenced mainly by two writers of the scientific method: Bacon and Descartes [3].

However, in reality the designer needs to go back many times to identify another problem or establish another solution [4]. The map should show a return loop from each function to all preceding functions. Apart from this problem, this map proceeds from general to specific, from 'outline proposal' to 'detail design', but several studies of practitioners' experience has proved that reality is messier. Lawson [4] argues that although for design to take place a number of things must occur, it is questionable that these things occur in order, or that they are identifiable separate activities. He proposes a map of the design process that is seen as a negotiation

between problem and solution through the activities of analysis, synthesis and evaluation.

Other authors have questioned the early attempts at formalising design methods that tried to break design problems down into their constituent parts, solve them and then assemble the solution. Hillier, Musgrove and O'Sullivan [5] disagreed with the A/S model and proposed a model of Conjecture/Analysis (C/A) that derived from Sir Karl Popper's account of scientific method. They believe that the rationalisation of the design process proposed by the A/S paradigm is unworkable because it suggests that design should derive from an analysis of the requirements of the users rather than from the designer's preconceptions, whereas in reality, a complete account of the designer's activities during the design process would still not reveal where the solution came from. They propose that the purpose of analysis is to test conjectures rather than optimise a synthesis by logical procedures. Design is a matter of pre-structuring problems by knowledge of solution types or by knowledge of the technological means in relation to solution types. Instead of displacing pre-conceptions, these authors emphasise the role of pre-structuring problems and the need of critical analysis of such pre-structuring in a process of reflective design. They believe conjecturing solutions early in the process helps to understand the problem; which is based on Popper's idea that constructing hypothesis or conjecturing is indispensable to inquiry and that there is great virtue in the making of mistakes.

The 'Popperian view of design' started to gain popularity in the late 1970's. The idea of conjecturing approximate solutions much earlier in the process than A/S allows the designer to structure an understanding of the problem. Darke [6] proposed an elaboration of the C/A model that consists of Generator/Conjecture/Analysis. She conducted a socio-constructivist research and observed that architects in practice tend to hold to a relatively simple idea or generating concept very early in the design process, which she called 'primary generator'. The benefit for the designer is that the primary generator reduces the variety of potential solutions. It is then tested against constraints and thus contributes to a better understanding of the problem, enabling one or more tentative solutions to emerge.

The body of knowledge of the design process has grown lately and many authors agree that the design process is less easily defined as a sequence of operations but rather by its overall characteristics. Schön [7] proposed an influential model of the design process as 'reflection-in-action', which is also influenced by Popper's ideas. He states that when practitioners approach the practice they acknowledge the complexity and uncertainty of the case; they do not act as they have no experience, but attend the peculiarities of the situation at hand. He defines design as a "*reflective conversation with a unique and uncertain situation*" [7], suggesting that the designer approaches the uniqueness and uncertainty of the design process by reframing the situation in an iterative process of appreciation, action and re-appreciation. The designer understands the situation through the attempt to change it and changes it through the attempt to understand it. In this process, the designer does not separate means from ends or thinking from doing.

In 2002, Bamford [3] synthesized the models of the design process under two principal paradigms that have their roots in different conceptions of the scientific method. The A/S paradigm proposes that design starts by dismantling problems into fragments, synthesising and evaluating possible solutions, and arose at the time when designers attempted to make design more rational and systematic and its powerful attraction was that design would emerge by a rational process from the brief, so that a design would be therefore justifiable. In contrast, the C/A paradigm proposes that design starts with ideas that can be quickly tested against constraints and that there is enormous value in making mistakes. The A/S model is mostly prescriptive and can be placed in the realm of design methodology, while the C/A model is mostly descriptive and can be placed in the realm of design theory.

INTEGRATED DESIGN PROCESS

The concept of Integrated Design Process developed by IEA Task 23 [8] is defined as a procedure that aims at optimising the building as an entire system and for the whole lifespan, achieved through interdisciplinary work from the beginning of the process. Some of the outcomes of IEA Task 23 are guidelines, methods and tools to assist collaborative teamwork in the design of high performance buildings. The approach of this study is generally methodological as it represents the design process as a complex flow chart of design decisions.

The study clearly states the differences between a traditional linear approach and an integrated design approach; and suggests that the design process starts by an overall problem that is dismantled into sub-problems and individual problems, reaching individual solutions and sub-solutions until achieving the overall solution (Figure 1). This definition can be clearly placed under the A/S paradigm.

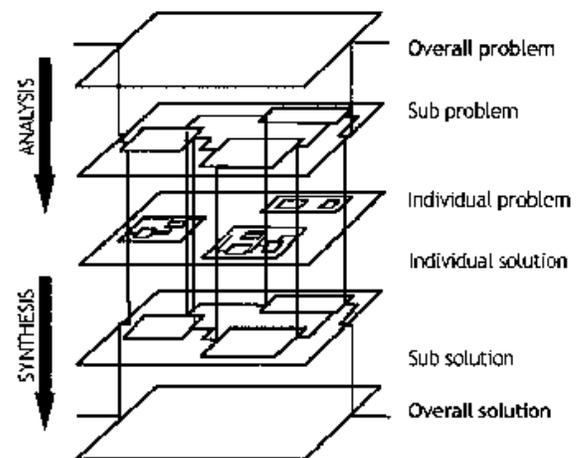


Figure 1: diagram of IDP by IEA Task 23

Within this model, the engineer is given a "*precisely defined problem*" and proceeds almost exclusively by a "*mathematically-shaped system of logic*", while the architect starts with a "*scarcely-definable problem*" and proposes a "*preliminary idea based on his individual experiences*" using a "*circle of hypothesis and analysis*" [8]. Therefore, the IEA Task 23 study places the engineer within the A/S paradigm and the architect within the C/A paradigm and tries to adjust a model of the design process that combines both competing visions. It is probably influenced by studies that suggest that scientists have a problem-focused strategy to design, while designers have a solution-focused strategy, which is probably true in the case of the majority of architects and engineers

CASE STUDIES

The research methodology of this study was based on case studies of architectural practices that are pioneers in integrating sustainability issues and low energy strategies in Europe and South America. The first stage of the research project included five European practices: Feilden Clegg Bradley Architects, Edward Cullinan Architects and Hopkins Architects in the UK, Behnisch Architekten in Germany; and Mario Cucinella Architects in Italy. The second stage included three South American practices: Enrique Browne, Guillermo Hevia and Roberto Martínez in Chile.

A sustainable building designed by each practice was chosen as an embedded unit of analysis in order to map the design process from the first ideas until completion. The buildings were suggested by each architect as good cases for being interesting in terms of integrating sustainability issues in the design process, and not necessarily for being the most sustainable or energy efficient buildings in their context. The selection of cases responded to a socio-constructivist approach that avoided having to impose a particular definition of sustainable buildings, but including different possible definitions suggested by each architect. The design process of each building was mapped through information gathered by different research tactics: interviews with the architects, engineers and clients; and through the analysis of graphic information and documents. The buildings are shown in Figure 2.

The cases studies suggest that architects would actually have ideas or conjectures first; they would not suppress ideas by attempting to do extensive analysis. Some architects would call this “*jump in and splash around*”, suggesting that the design process starts with an idea that is holistic in nature, which can be tested against different constraints at a later stage. This way of proceeding is certainly closer to the C/A than to the A/S paradigm. All the architects interviewed in this study proceed in a similar way; having ideas that are based on knowledge and experience before actually testing these ideas against the constraints.

The integration of environmental sustainability issues in the design process does not seem to alter the C/A nature of the design process, but it actually seems to reinforce it. The first ideas (or conjectures) expressed in the first sketches of each case study deal with different architectural problems, particularly sustainability problems, in a synthetic way. The first idea is integrative by nature and it is unlikely that integration could be achieved by analysing enormous amount of information, synthesising and evaluating it until finding the optimal solution, as the A/S model suggests.

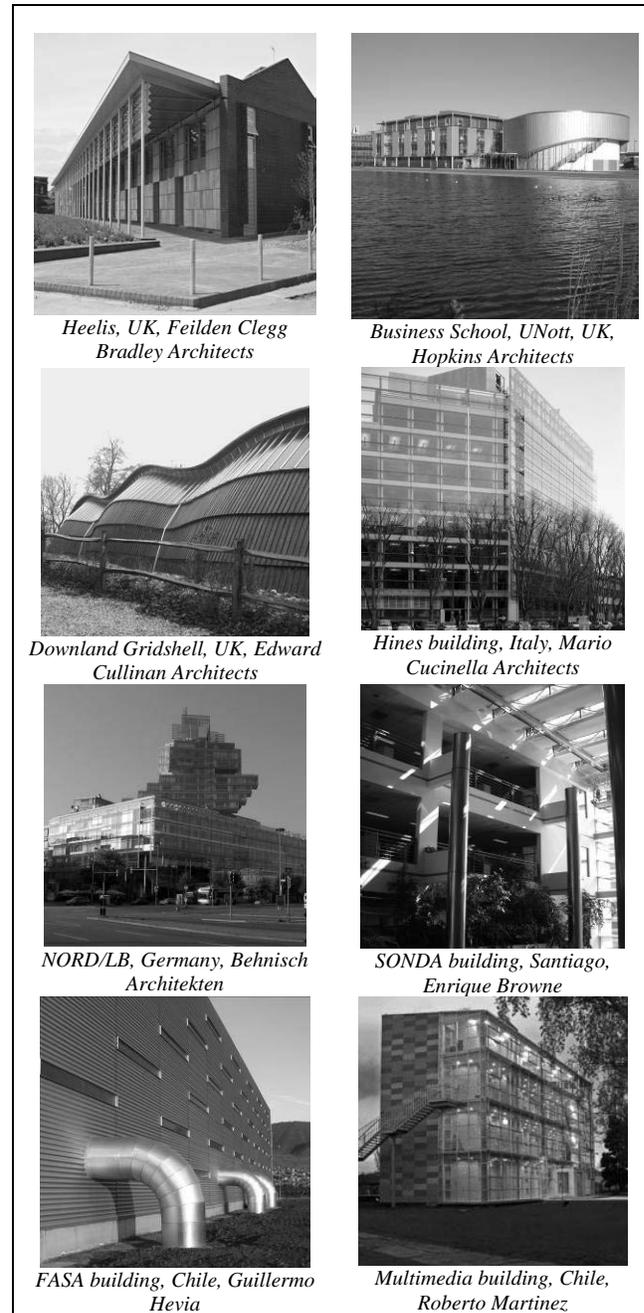


Figure 2: Case studies

The impact of integrating environmental sustainability with the C/A model of the design process points towards two implications. First, the generation of the first idea (or conjecture) is the result of a social process of interaction of differing expertise, which is the base of the Integrated Design Process. The case studies have shown that architects and engineers start working in close collaboration from the beginning of the design process to the point where on occasion both parties share the authorship of the first idea. Second, analysis plays a crucial role in the design process, going beyond the

common notion of analysis as the process of qualitative appreciation and re-appreciation of the design situation, into a process of quantitative assessment that informs design decisions, supported by tools. Quantitative analysis is intrinsically linked to the technical challenges of sustainable architecture and it was present in all case studies, but at different levels of sophistication depending on the complexity, innovation and risk involved in the project. The role of the analytical process is particularly important during middle to late stages of a project, and the whole process may be understood as a reflective interaction between intuition and analysis. Before embarking on extensive analysis, the design team would use intuitive elements to generate ideas, while subsequent analysis would allow them to get a better understanding of the environmental problems to iterate back again in reflective practice.

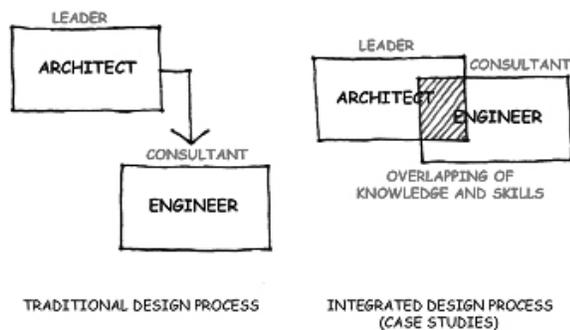


Figure 3: Integrated Design Process under the C/A paradigm

As explained above, some studies on the Integrated Design Process places the engineer within the A/S paradigm and the architect within the C/A paradigm and tries to adjust a model of the design process that combines both competing visions. It is probably influenced by studies that suggest that scientists have a problem-focused strategy to design, while designers have a solution-focused strategy. The findings of this study question this model that takes the traditional characters of the architect and engineer and combines them in an abstract manner, failing to recognise that the integrated approach needs more substantial changes that tackle the bases instead of the methods. It requires architects and engineers to get closer in terms of sharing knowledge and skills. The architect needs to develop knowledge in architectural sciences and skills in simple environmental analysis, while the engineer needs to develop knowledge in architectural matters and skills in design. They share a common language, as well as sharing the character of designer. Instead of combining the A/S and the C/A paradigms, they both operate under the same C/A paradigm (Figure 3).

The idea that the integrative approach to the design process, which is essential to sustainable design, requires that the architect and engineer overlap their knowledge and skills and share the character of designer has interesting implications for education. It stresses the necessity for each discipline to cover basic and essential knowledge and skills of the other, resulting in architects and engineers with a new character, different from the traditional one.

RESEARCH vs. PRACTICE

The conflict encountered between research and practice derives from the fact that some research in the field rejects the role of intuition and insists on the necessity of making the design process scientific. Although most research recognises that early design decisions are driven by intuition, this is seen as unsystematic and unscientific. However, the intuitive process is not less systematic than the analytical process. It is based on the solid elements of knowledge and experience and it makes use of appropriate tools, such as precedent, rules of thumb, strategies and principles. There are researchers who believe that the A/S paradigm is still a more appropriate model to describe the integration of environmental sustainability in architecture than the C/A paradigm. They perceive the A/S paradigm as being scientific and less dependent on the designers' caprice, which matches better with the technical view of sustainable design. Most of research in this field is focused on developing design-assisting tools that seeks to diminish the role of intuition particularly at early stages of the design process and replace it with scientific analysis, which they view as essential means of achieving an environmentally sound solution.

This approach resembles the tradition of systematisation and functionalism in architecture that proposed that architecture could be produced by calculation. According to Heath [8] this approach committed two fundamental mistakes: to suppose that any set of abstract relationships can be sufficient to determine the form of a building and to think that the result could be either intelligible or aesthetically acceptable. He highlights the role of intuition claiming: "the mind can do more than inference and association would permit" [8]. Although at first sight it might be felt that environmentally sustainable design is facing the risk in the face of pressure to adopt similar approaches, the reality of practice is completely different. There is a gap between an area of research and practice of sustainable design that is based on different paradigms of the nature of the design process, i.e. A/S versus C/A (Figure 4). However, it is important to note that the A/S paradigm is held by some researchers in the field of performance simulation and architectural design, by not by all.

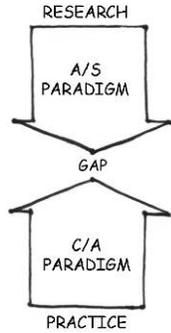


Figure 4: confrontation of paradigms between research and practice

In fact, this gap is not fundamentally different from the ‘applicability gap’ that Hillier, Musgrove and O’Sullivan detected in their seminal paper written in 1972 as a reaction against the dominant A/S model that implied that research should bring as many factors as possible within the domain of the quantifiable, replacing intuition with methods of measurement [5].

THE WHOLE AND THE PARTS

The confrontation between the A/S and the C/A paradigms has also had an impact on the development and application of non-interactive tools, such as sustainable checklists, methods of environmental assessment and element catalogues. In the same way that the A/S paradigm concentrates on dismantling the parts as a way of reaching the whole, most of these tools are focused on the parts, as a result of their own nature of ticking boxes. The problem is that in architectural design “the whole or aspects of the whole govern the parts” [2], so tools that focus on the parts cannot guarantee that the whole will be coherent. They might guarantee that the whole is more or less sustainable, but their role as design-assisting tools is confined to one-line decisions (a part), such as the specification of a sustainable product or material. This role is still very valuable, as one-line decisions can reduce the embodied energy or the overall energy consumption of the building, but if taken on their own (essentially ticking boxes), without considering the integration of the parts in the whole, there is a risk of parts becoming add-ons of the building, jeopardising its overall coherence. Nevertheless, there is still value in raising awareness of the issues because it builds up motivation and knowledge in architects to explore strategies for integration.

This tendency of dealing with the parts to reach the whole represents one of the elements that alienate sustainable architecture from mainstream architecture. Usually, architectural quality has been assessed by its overall success instead of fragmented achievements, which makes it difficult to combine both realms.

Nevertheless, as a result of their ability to deal with the parts, checklists have proved to play an important role for managing the sustainable agenda of the project.

Remarkably, the case studies suggest that the best sustainable design advice is expert advice. The general approach to dealing with specific matters of sustainability was to look for an expert to assist the design team in that area, who eventually used appropriate tools to support his/her work. This was often the case when the problem was so specific that designers were unlikely to find a solution in a guideline. This approach is expert-oriented instead of tool-oriented; it is a bottom-up approach instead of a top-down approach. It also places expertise and interdisciplinary collaboration in parallel to the use of tools.

Although precedents or case studies could be interpreted as prescriptive advice and also closely dependent on the local context, architects in reflective practice are able to identify the elements of the precedents that match their requirements and adapt them to their own needs. Therefore, architectural case studies seem to provide valuable non-interactive tools based on their ability to deal with the integration of different strategies in the whole. Most sustainable design guidelines have recognised this fact and include a section on case studies, but usually limited to a brief fact-sheet that fails to provide a comprehensive understanding of the case.

Methods of Environmental Assessment, such as BREEAM and LEED, follow an A/S approach of dealing with the parts to assess the whole. The case studies suggest that architects do not generally regard them as playing an important role in the design process, but they believe that these methods provide valuable certification when the client requires it and they can become a tool for quality assurance.

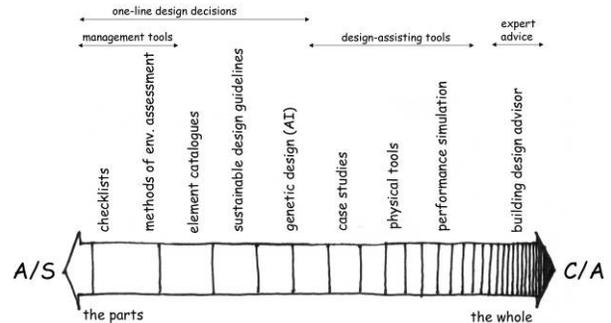


Figure 5: position of tools according to A/S and C/A paradigms

Based on this idea, the most important tools for sustainable design can be placed along a continuum according to their relation to the A/S or C/A paradigm (Figure 5). Checklists, methods of environmental assessment, element catalogues, sustainable design

guidelines and genetic design based on Artificial Intelligence (AI) are built upon A/S logic of decomposition and re-composition. The parts are more important than the whole, so they provide valuable tools for project management and assisting one-line decisions (specifications). On the other hand, performance simulation tools, physical tools and case studies are closer to the C/A logic in that they assist design decisions that integrate several variables, so that the whole is more important than the parts.

This diagram does not propose that some tools are more appropriate for early stages of the process, while others suit later stages because architects tend to deal with the whole and the parts simultaneously. It rather proposes that different tools would serve different purposes in the design process.

CONCLUSION

The C/A perspective to the Integrated Design Process that suggests that both the architect and engineer proceed in a similar manner of having ideas that are then tested against the constraints, have interesting implications for education. As it requires that the architect and engineer overlap their knowledge and skills and share the character of designer, it stresses the necessity for each discipline to cover basic and essential knowledge and skills of the other, resulting in architects and engineers with a new character, different from the traditional one.

In addition to the implications for education in engineering and architecture, there is an emerging trend that identifies this area of overlap and isolates it as a discipline with its own character. This is the case of the new career of MEng in Architecture and Environmental Design, which addresses both the architectural and engineering challenges of the integrated approach to sustainable design.

There are also some implications of the diagram in Figure 5 for research and policy making in orienting the evaluation and promotion of sustainable architecture. It suggests that expert advice – although not literally a tool - is proving to be the best way of dealing with integration, so governmental initiatives should support them as instruments to tackle sustainable design. It also stresses the need for the dissemination of detailed and rigorous case studies with clear reference to the context as means of guiding integration. It finally stresses the need for revising the methods of environmental assessment that are being adopted by governmental initiatives in view of their rigidity and lack of ability to deal with integration.

ACKNOWLEDGEMENTS. The first stage of this research project was done with the support of ALBan Office and MECESUP, while the second stage was done with the support of FONDECYT, project N° 11070148 - Universidad del Bio-Bio, Chile.

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