HMC/ARCHLAB High Performance Design Process:
Enhancing Design with Science

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ABSTRACT: This paper describes a High Performance Design Process (HPD) that enhances the traditional architectural design process promoting the design of sustainable, high performance buildings. This process includes the creation of performance targets, the generation and evaluation of design ideas, feedback from real-time building performance, and knowledge sharing with the design teams and the community. This HPD process has been implemented in practice in the firm HMC Architects and in architectural education at Cal Poly Pomona's department of architecture. It is under continuous development and has improved the performance of projects in both environments.
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INTRODUCTION

To reduce anthropogenic emissions and have any real impact on climate change, it is necessary to improve the performance of the buildings that we design by reducing their GHG emissions, energy and water consumption, and production of waste.

Architects should know how to design buildings with a reduced environmental impact and the objective of this HPD process is to help them in this process. Furthermore, the process is flexible and adaptable and can be adjusted to different scales and requirements.

ARCHITECTURAL DESIGN PROCESS

The architectural design process is an iterative problem solving process in which sequences of sub problems that are not well defined are solved. During this process the documents to generate a building, which must satisfy many different criteria, are produced. Traditionally this process begins with a series of diagrams and sketches that illustrate the architectural concept. These sketches are progressively refined with the addition of different criteria until the final proposal is developed.

The architectural design process is intimately related to the process of problem solving, which in very general terms means that we need something but do not know precisely how to obtain it. Rittel [1] proposed the existence of an alternating generation and reduction cycle, which repeats itself continuously in the design process improving the quality in each cycle. Furthermore, the architectural design process is a complicated one in which the architect in which the architect must consider many issues and then generates and evaluates multiple solutions to finally produce a sufficiently refined object which fulfils the requirements of sometimes conflicting ideas or programs. It is crucial that any process to improve building performance, or sustainable performance be integrated with the architectural design process and with the process by which the architect develops design ideas to achieve a project.

During the architectural design process the documents to generate a building which must satisfy many different criteria, are produced. Traditionally this process began with a series of diagrams and sketches that illustrated the architectural concept. These sketches were progressively refined with the addition of different criteria until the final proposal was developed. This process has changed dramatically with the widespread implementation of Computer Aided Design tools CAD and could change even more with the move to digital fabrication.

A CAD tool can be any computer program that helps the architect to solve an issue during the architectural design process. The ultimate objective of all CAD tools is to improve the product by improving the design process. However, CAD tools should also be easy to use. La Roche and Liggett [2] proposed Very Simple Design Tools (VSD Tools) that are easy and simple to use, so that more designers can use them in more affecting more buildings. It is in the spirit of very simple design tools that this carbon neutral design process is proposed. This process is like VSD tools, easy to use, easy to learn, precise, fast, accessible and flexible. However it is as good as the designer's knowledge and is only a guide, augmented by the designers' knowledge and experience.

HIGH PERFORMANCE DESIGN

The Energy Independence and Security Act [3] of 2007 defines a high performance building as a building that integrates and optimizes on a life-cycle basis all major high performance attributes, including energy conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality and operational considerations. However, there is no clear threshold that indicates when a building becomes a high performance building, partly because performance is usually described by how it compares to specific codes such as an energy code, which vary from country to country and even from state to state in the United States. A High Performance Building must have a considerably better performance than similar buildings in the same location and climate. If the Commercial Buildings Energy Consumption Survey CBECS [4] is used as reference, a high performance building designed in 2013 should use at least 60% less energy than a CBECS building for that building type and location. A building designed to this standard will also comply with Architecture 2030's challenge for buildings [5].

A High Performance Design Process (HPD) must be integrated with the design process, it is not a separate process. High performance design must promote design thinking, enhancing it and promoting more opportunities for the development of sustainable, high performance building solutions. It combines digital and analogue tools in different phases of the design process to improve the quality of the final product. This process is flexible and should be thought as an overlay instead of a rigid series of steps.

The HPD process parallels project development from predesign to post occupancy. The first step is implementing eco-charrettes that establish performance targets, energy simulations and physical prototyping to analyse and predict impacts of sustainable strategies, feedback mechanisms analyse and synthesize real-time building performance and finally knowledge sharing strengthens high performance applications.

The HPD process is easy to adapt to different types of projects and scales and incorporates appropriate tools and strategies to evaluate ideas during the design process. Ultimately, buildings should have a reduced environmental impact measured by how they affect climate change and resource consumption; promote human health and quality of life, and benefit society while providing added value to the community. Building performance is measurable using appropriate metrics for each of these areas: energy use intensity (EUI) in W/m^2/yr; GHG emissions in kgCO^{2}e/m^2/yr; of water consumption in m^3 water/m^2 surface/yr; kg CO^{2}e/m^2/yr embodied in materials.

Figure 1, based on the carbon neutral design process developed by the author [6] illustrates the process implemented in design studios and architectural projects. This diagram specifies knowledge areas that can be implemented to improve building performance in different areas. The diagram is, as the method, flexible and can be continually refined and updated as needed. For example this version of the diagram focuses on strategies to reduce building emissions. These are produced as a direct result of interactions between the building and the external environment that surrounds it and can be affected by the building fabric and materials or the building's inputs and outputs (operation, construction, water, waste). Other emissions such as transportation, are affected by building location but are not produced by the building itself nor as a result of any of the building's inputs and outputs.

In figure 1 the four horizontal rows are the sources of emissions previously discussed: operation, construction, water and waste. In other projects more rows have been added to include other variables such as transportation and culture. The first column describes the baseline requirements, while the final column describes the outcomes. The columns between these two are scales in the process, and can be adjusted depending on project scope, usually regional, urban, site scale, building envelope and finally the interior of the building. Different emission reductions strategies are located in these knowledge areas at the intersection of the columns and the rows. Some of these can reduce the emissions from the building while other strategies actually perform as carbon sinks. Knowledge areas that reduce the carbon emissions are enclosed in rectangles while areas that are carbon sinks have a thicker border around these rectangles.

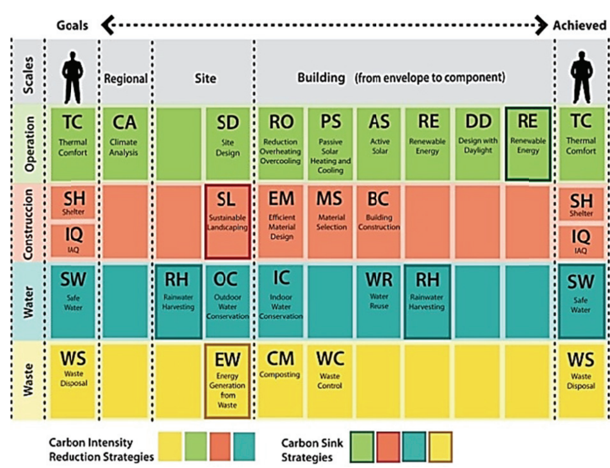

Figure 1: High Performance Design Diagram

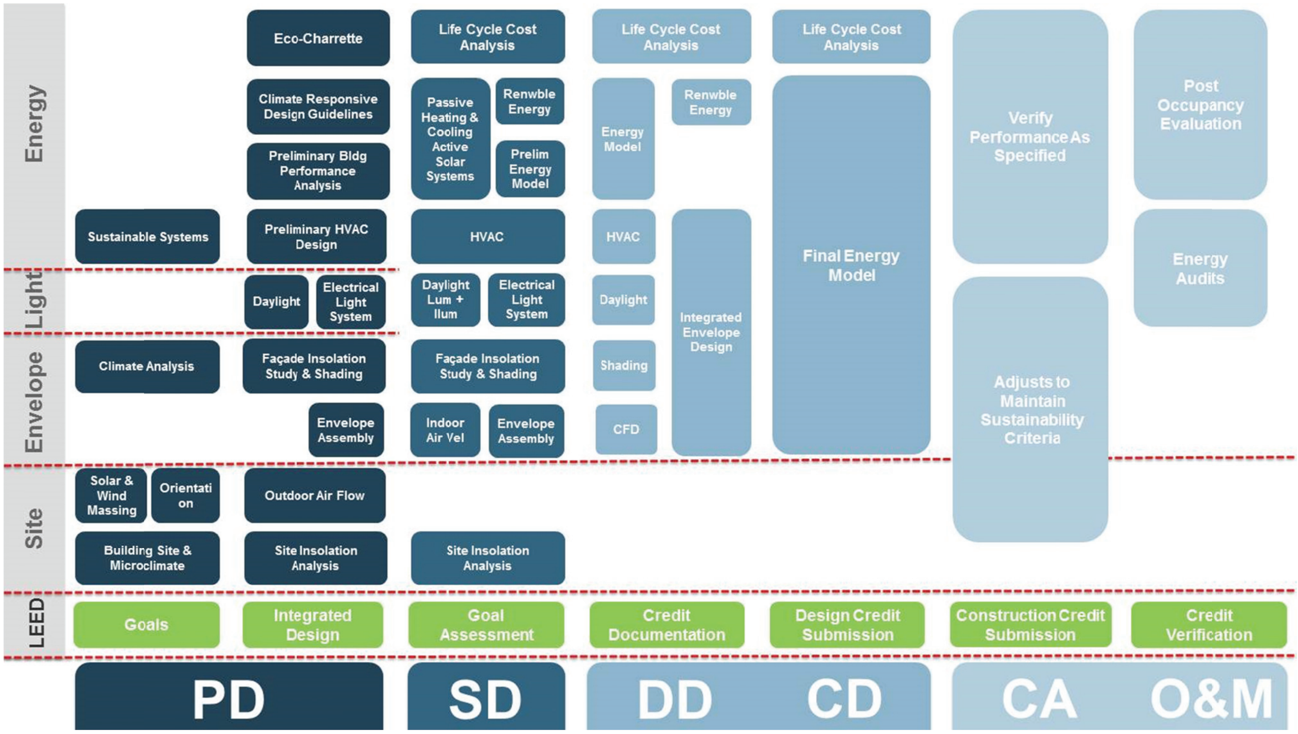

Figure 2: High Performance Design Process with strategies and design phases

Because figure 1 does not link the strategies with the design phases, another diagram is needed to understand this relationship. Figure 2 looks in more detail at the activities and strategies in this process and how they are linked with the phases in the design process. The vertical columns indicate the phases, Pre Design PD, Schematic Design SD, Design Development DD, Construction Documents CD, Construction Administration CA, and Operation and Maintenance O&M. The horizontal bands organize the topics that designers deal with during the design process: site, envelope, light and energy, with the different strategies and processes in the different phases. The position of these topics and their contents can vary by project and designer. These activities can also occur in different phases, with increased complexity as they develop. For example daylight design occurs in PD, SD and DD. Different High Performance Design Processes don't have to include all strategies indicated in this diagram and can also include other strategies. Some of the strategies are discussed in the following sections.

Ecocharrettes

Eco-Charrettes are an important step to establish a high performance design process. It is held as early as possible during the schematic phase of the project, and clearly identifies opportunities for sustainable strategies. This provides a forum for the user group representatives to voice their visions and goals, and to exchange information about opportunities that might be pursued.

The Eco-Charrette is divided into several sections that range from the description of the vision and goals to the discussion of strategies needed to achieve the goals. The result is a focused plan for sustainable practices based on opportunities identified by the eco-Charrette participants, serving as a catalyst to analyse and evaluate potential sustainable strategies using evidence based design.

The first part of the eco-charrette consists of a sustainability visioning exercise in which the user group members voice their sustainability interests, aspirations, and goals for the project without the bias of external information.

The second part includes the analysis of the existing environmental conditions using a variety of programs such as Climate Consultant, Ecotect, and Vasari to analyse and present climate data (Fig 3). In some cases solar effects including shading, and wind patterns across the site are presented. This analysis establishes a shared understanding of the climatic context.

The third part of the ecocharrete includes three parts with a more in depth discussion to determine which sustainable strategies would help to better achieve the aspirations voiced in part one. The participants are asked to record their ideas onto Post-it notes that are then attached to a large High Performance Design Diagram based on figure 1 developed and adapted for each specific project (Fig 4), but in which the strategy rectangles are empty. The chart is used to graphically organize and record the Charrette participants' goals and strategies to reduce the building's environmental footprint. In this way, the chart is custom made for the project using input from all. We are in the process of developing a tablet application that will record information digitally and track the project's progress in these areas.

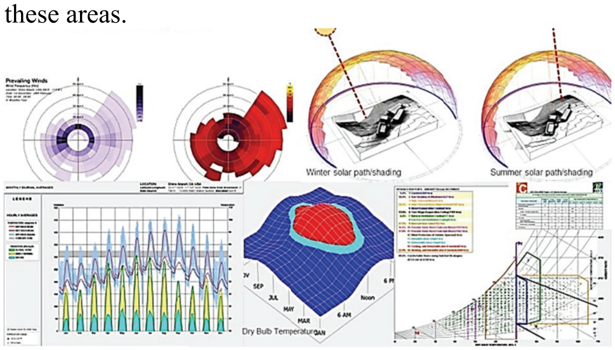

Figure 3: Example of Climate Analysis in the second part of the Ecocharrette

During many ecocharrettes, we are able to graphically record the process, documenting the results of the ecocharrette (Fig 5). The charrette participants discuss how the various strategies translate into potential scores using various rating systems such as Architecture 2030, The Living Building Challenge, LEED, CHPS, or STARS. Finally, the attendees discuss how the ideas discussed in the first parts of the charrette could inform the building and site design. Ideas are sketched out while referencing the climate analysis material. Design opportunities are identified and will serve as a foundation for the project. The result of the ecocharrette includes sustainable design goals developed by the team and sometimes simple massing and design concepts.

Figure 4: Graphical recording in an eco charrette

Simulations

Simulations are an important part of a high performance design process. They are used in the *evaluation* portion of the generation-evaluation cycle. Simulations allow to quantify the effect of different design decisions, permitting to compare different scenarios. Simulations should be performed from the initial design phases and during all phases of the design project to evaluate design ideas. They are usually implemented to determine code compliance and design performance.

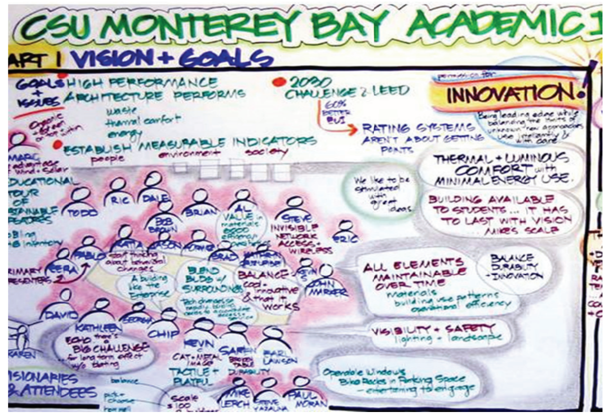

Figure 5: Example of Ecocharrette Graphic Recording

Modelling for code compliance is typically done for energy consumption, the main performance variable regulated by code in the United States. It compares the calculated energy use of the designed building with a reference baseline building to demonstrate that it complies with minimum performance criteria. Buildings in some countries must also demonstrate that their GHG emissions are below levels of a reference building. Performance modelling based on GHG emissions will be more common over time.

Modelling for design performance is done throughout the design phase to quantify several parameters, some of which are not required by code. In this case modelling is implemented as an evaluation tool to determine the project performance compared to goals set in the ecocharrette, green building accreditation systems such as LEED, or a utility incentive program. The goal is to design a building that will outperform a reference building, which is usually the code minimum, demonstrating a higher level of performance. In addition to energy, modelling usually includes other variables such as illuminace and luminace levels, carbon emissions, water consumption, embodied energy, and life cycle cost of materials. Modelling for design performance is important because it improves building performance.

The high performance design process has been implemented in several projects. Figure 6 is an example of the diagram developed as part of HMC's proposal for the Taichung Tower competition. In this project we estimated the carbon footprint using different tools to evaluate performance in the different areas indicated in the diagram and then adding them.

Figure 6: Example of High Performance Design Diagram used in HMC's proposal for the Taichun Tower competition

It is also possible to evaluate the performance of projects using the variables previously mentioned, determining their impact and then the total carbon footprint. The information is grouped and expressed in different types of diagrams such as figure 7.

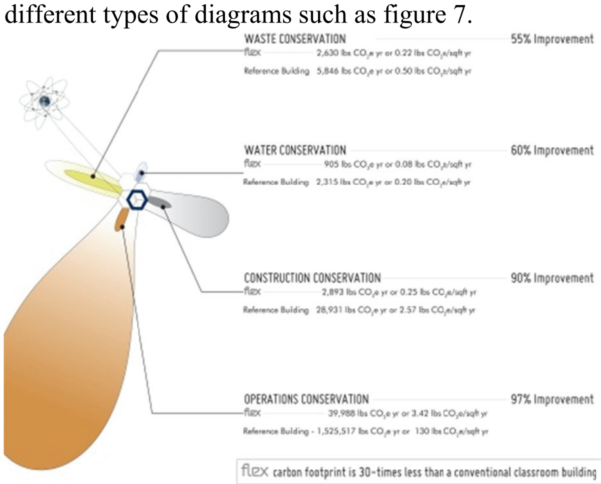

Figure 7: Example of evaluation tool developed as part of HMC's proposal for the Flex School Competition for Los Angeles Unified School District.

An example of one of the processes is the insolation analysis of surfaces (Fig. 8) proposed during SD for the envelope section (see Fig. 2). This is used to determine shading requirements and potential for active and passive heating strategies and production of renewable energy. This analysis can also be combined with wind studies to determine outdoor thermal comfort during different seasons.

Integrated analysis of the envelope includes the analysis of components as a function of solar gains during peak cooling loads, daylight (luminance and illuminance) and energy consumption. This integrated analysis process can be used to study different envelope components, for example window and shading options to select the best overall solution.

Performance and Verification

It is important to determine the actual performance of the project and the occupant's satisfaction with the project [7]. Because of their rigorous systematic assessment of past successes and failures, post occupancy evaluations can build knowledge, improve future designs, and demonstrate the contributions of the design professions to the community.

Figure 8: Insolation Analysis on Horizontal and Vertical Surfaces

The comparison between the design intent and the real performance can be analysed using measurement and statistical models and both subjective and objective measurements. For energy performance, the comparison between the energy models and the actual usages is important. Based on the findings of some of our POEs, corrective measures have been taken to remedy the buildings and enhance the building performance.

EDUCATION AND TRAINING

Education and training is important because by increasing the designers' knowledge it improves the quality of the projects that they design and the quality of life of the occupants. Even if education is not a part of the high performance design process, education is a very important component in the process for a successful implementation of these strategies.

Professional Training

A High Performance Design process will not be implemented if architects and designers don't understand and embrace it. Workshops, presentations and retreats should be developed to train staff in sustainable design methods and strategies. We have done several on different topics, such as climate analysis, shading design, daylighting (Fig 9) energy modelling, eco charrettes, carbon neutral design etc. We have combined the use of interactive modelling tools with the use of physical models.

Figure 9: HMC designers in a daylighting workshop

Figure 10: Workshop for elementary school children with a student from another country asking a question.

Community Service and Social Responsibility

Education outside the firm is also important. We have focused on elementary school children and have developed a series of workshops on environmental sustainability that we have done in several locations.

At McKinley elementary school in Santa Monica, California, we did three workshops, on energy, water, and waste, each of which included an interactive presentation that employed a variety of teaching techniques including interactive group discussion, movement, art, music and multi-media videos. After the presentation, students broke up into smaller groups to engage in hands on activities in which children further explored the contents of the presentations. Cal Poly Pomona student volunteers, teachers from the school and volunteers from HMC Architects facilitated the workshops and hands on labs. In addition to local students, students from a school in Venezuela participated via Skype (Fig 10) in the presentations and asked questions while local students engaged with them using laptops with cameras. As a way to disseminate and share material from the sustainability education program, we are producing a book on sustainability for elementary school students. In addition, the team will develop a teacher's guide so that educators can bring this experience into their own classrooms.

These educational activities seek to help train the next generation of environmental stewards to positively impact our planet and effect systemic change. Our hope is that the project will have a ripple effect. We expect children to share what they learned with their classmates, families and communities and inspire us all to take action. The workshops have provided students with a worldview perspective of environmental issues increasing their awareness and giving them practical suggestions on how they, as elementary school children, can build a better planet for all.

CONCLUSION

The performance of projects in which this method has been implemented at HMC has improved over time. The energy consumption of projects under design has improved (36% below CBECS to 49%) by using better collection and accounting methods and by the implementation of the previously described strategies: the eco charrette to determine the goals, the evaluation of design ideas and performance through modelling tools, and in a much smaller scale design verification to determine real performance of the building. Empowerment of the firm's designers through training and education has also been an important part of this process that cannot be ignored. However, even though there is progress, much has yet to be done: increased costs of high performance design, both in the process and in construction, is always an issue, and resistance from owners and clients to POE's is still a challenge.

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