Sustainable Design Processes

SUSANNAH DICKINSON

School of Architecture, University of Arizona, Tucson, AZ, USA

ABSTRACT: This paper will present the work of a related undergraduate architecture design studio, ‘Sustainable Skyscrapers’, which took place in the fall semester of 2011 at the University of Arizona. In this studio the intent was to find ways of form-finding verses form-making; using natural and built infrastructure, systems and flows to create new design strategies, relationships and building typologies. The studio’s stance was that it is not okay to maintain the status quo, but that we need to fundamentally rethink the direction we are moving in. Emphasis was placed on research as a speculative and iterative process rather than on final products. Design is becoming more holistic as we become more environmentally conscious. Projects needed to emphasize cycles, feedback loops and inter-connectivity, akin to a more ecological model found in nature. Linkages between digital technology, biomimetics and sustainability were made as they all stem from the same aspirations in the study of systems.

Keywords: biomimetics, digital technology, sustainability.

INTRODUCTION

Sustainability is not a new issue. The Brundtland Commission in the late 1980’s defined sustainable development as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs.’ Recently there has been more mainstream acceptance of environmental concerns in the wake of the current global economic crisis, population boom and global warming. The building industry and urban environment are major players in this environmental crisis: the U.S. Department of Energy reports that the commercial-built environment produces 48 per cent of the nation’s greenhouse gases annually and 66 per cent of all electricity generated by power plants is used to operate buildings. For these reasons alone it is apparent that building processes, resources and systems should be critically reviewed. The environmental concern is not just about the shortage of future natural resources, but about the effect the pollution and waste has on human health issues and further environmental impacts. Awareness is rising, in our increasingly globalized society, of the connection between environmental, social and economic issues. This inter-connectedness was explored in the students’ work to varying degrees and successes.

CONCEPTUAL FRAMEWORK

Making sure buildings ‘perform’ responsibly is a key issue today. Innovation and technological advancement are not important for their own sakes; developments need to be balanced in consideration with available resources and human culture and psychology. One of the main shifts that need to be made is away from the pressure of short-term goals to longer term ones. Nature is the ultimate in performance-orientated design so it is no wonder that attention is finally being paid to its processes. This coupled with increasingly levels of knowledge and technology set the stage for a new level of ecologically-based design. Architecture has hopefully moved past the idea of single object buildings and is gaining focus on a more ecologically-based, systems approach, like nature, where organisms function in relationship to each other and their entire surroundings. In our Information Age one of the main information areas that certain architects are looking at is of the natural world. Technology can help us understand these natural systems at another level then we previously had known.

The study of biomimetics (the abstraction of good design from nature) is increasing in architectural curricula across the world. The author had previously published a paper in the area of biomimetics which was passed along to the students to expedite their research and design process. The main features of natural systems were stated as follows:

1. Good economics of energy and materials: optimization.
2. Rich, diverse systems from small, relatively simple components and materials.
3. Form, structure and material are generally all interconnected.
4. Survival techniques are maximized: e.g. carrying capacity, the relationship to surrounding...
environments (ecological), usually always process-driven systems.
5. Always dynamic systems: all nature is constantly changing and adapting.
6. Self-organization techniques are utilized; they produce emergent behaviour, from sub-cells to ecosystems (systems within systems).

One could argue that items 1 through 4 are the more straightforward examples that are well on the way to being achieved in architectural design today and items 5 through 6 are potentially more extreme. Understanding these in relation to how natural systems operate is more complex though. For instance with regards to optimization, this historically has been treated very differently in biology verses buildings. In biology to achieve efficiency and optimization there is a high amount of redundancy and complexity in the material hierarchies. This redundancy allows adaptation to changing environments, and is a much less linear approach to the way we usually engineer buildings. Biology’s stochastic process, rather than a deterministic one, generally means that the standardization of components and members is precluded. With regards to materials, “biology makes use of remarkably few materials, and nearly all loads are carried by fibrous composites; cellulose in plants, collagen in animals, chitin in insects and silk in spider webs.”[1] They work not because of this fact alone, but because of the way they are put together. These materials generally provide higher levels of optimization than ones which are more homogeneous. Generally, they are good in tension and bad in compression (tension based systems per weight are usually more efficient than compression systems).

Ecological, inter-connected systems in the natural world have no separation of form, structure and material: they all act on one another and cannot be predicted by the analysis of any one separately or in a different context.

One of the pedagogical challenges was to tie together all of the necessary strands for success: comprehensive design, biomimetics (including human aspects), environmental concepts and digital methodologies. Digital Technology holds a fundamental role in this time of rapid change; various digital platforms and their interoperability were explored to accommodate the most effective work-flows e.g. parametric and algorithmic design tools and analysis software. Emphasis was given to ‘digital agility’ rather than dependency on one particular software platform. Linkages between digital technology and sustainability were made as they both stem from the same aspirations in the study of systems and connections (relationships). This was fundamental in the use of parametric modeling tools where students began to think in terms of relationships verses single, isolated objects. “Parametricism founds its design research program on a totally new ontology – an ontology that abandons the Classical/Modernist compositions of inert, rigid geometric figures and puts in their stead a world of malleable, adaptive elements (radicals) that engage with each other to form differentiated systems which in turn are associated with each other via scripted dependencies.”[2]

Students were required to think critically about their choice of parameters, going beyond mere formal explorations. This entailed developing ways of integrating design techniques and system performance. It was not just about mastering computational techniques, but a mode of computational design thinking, always encouraging students to work smarter not harder. The development of Building Information Modeling and Integrated Project Delivery (BIM/IPD) is, in theory, pushing us to a more integrated, cohesive model of working. We need to make sure we are not just using this methodology to do business as usual though. Using a 3d digital database model in itself does not imply an inter-connection of systems with its environment. It merely implies more potential coordination of existing rules of design and construction. We need to see buildings as interconnected, dynamic ecological networks.

STUDENT WORK
The following work is from a fifth year, undergraduate architecture studio which took place in the fall semester of 2011, at the University of Arizona, Tucson, Arizona, USA. This ‘Sustainable Skyscraper’ Studio’s premise assumed a desire to increase density where appropriate and to protect the natural landscape from urban sprawl as much as possible. Initially it was clear that sustainability needed to be defined in broader terms than the systems/relationships related to biomimetic and environmental performance concepts. It needed to include social and humane aspirations too. This led to the understanding that density alone could not solve all of our current environmental and economic problems (Fig.1).

Designer Input into Site and Program
Students were encouraged to pursue their own program and site, although defaults of New York City and Hong Kong were suggested. The site selection and program processes had a major impact on design outcomes. The initial decision about which program(s) a project should include and where the project should be located are
fundamental in developing a more sustainable trajectory. One key example of this was the proposal by Shaun Poon to add a vertical textile factory in the financial district of Hong Kong (the Central District). The Central District is an area of Hong Kong that is currently facing many economic challenges dealing with the topical issue of big-business verses the regular people. Shaun’s design hypothesized on how the poorer 99% of the population could regain control of their own lives. The proposal introduced a mixed program of a Silk factory (China is the largest silk exporter in the world) and living quarters whose aim was to be a catalyst to start to readdress the environmental, social, and economic issues in the area. The presence of a factory would help to educate a generation that has had an increasing detachment to the process of making and understanding where their products come from. It would also reintroduce the business of making as an asset in the corporate dominant district. Environmentally friendly closed loop systems were implemented in the production of the textiles (mainly silk), which turned the manufacturing by products into nutrients that were then redistributed back into the factory and living units creating a sustainable cycle of production. The project changed the concept of waste, turning it into value, which could then be beneficial on multiple levels. Programmatically creating a factory that had production and distribution in house meant there would be less energy wasted during the exportation process of products too. The live/work scenario meant that energy getting to and from work was reduced which would also save time and money. This would also provide life in the neighbourhood past typical peak hours of the business world. The creation of a more localized network can be beneficial in building a self-sufficient community that begins to give back to the economy rather than take from it (Fig. 2). The Silk Factory’s program and site selection dismisses the current segregation of most cities manufacturing areas, encouraging new, clean manufacturing to occur everywhere and promoting new depths of live/work adjacencies.

**Figure 2: Existing verses Proposed Supply Chain of Factory materials. (Submission by Shaun Poon, BArch Candidate 2012)**

Mixed-use ultimately is a key component to social, environmental and economic sustainability for the masses. One project labelled this mixed use, ‘a city within a city’ (Fig. 3). Students took the social diversity aspect to different levels, some arguing that it was not just about mixed-use, but a greater need for social equity which would enable true sustainability.

**Figure 3: Typical Tall building Program distribution (left) verses Proposed Mixed Use Program (right) (Submission by Karen Costello and Kori Camacho, BArch Candidates 2012)**

The student-led programmatic and site selection process takes time out of the studio’s semester, but is a key element which engages the student on a much deeper level then if both of these elements were prescribed for them. Site selection was important on several levels; some students responded to the concept of transit oriented development, with one actually combining the transit center within their design, while others were more influenced by natural factors. Sulaiman Alothman, proposed the formation of a new building typology in Kuwait City, Kuwait (Fig. 4).

**Figure 4: Wind form-finding drawings. (Submission by Sulaiman Alothman, BArch Candidate 2012)**
The project combined the widespread water towers with desalination plants, agriculture, and living areas to compose an integrated architecture which responded to the urban conditions along with the natural elements and processes. The towers were placed in response to the wind patterns which occurred in the different seasons in the city. They were placed in high density areas in order to harvest the wind for passive heating and cooling purposes. Additionally systems such as sea water, brine from desalination, fish-waste from sea water, water from farming etc. were intertwined, delivering and transporting the necessary resources for sustaining the ‘living’ tower. Wind also influenced the form of the tower itself, maximizing the passive flows allowing for natural ventilation and cycles related to these systems.

Passive Strategies First
Low energy, sustainable towers imperative is to maximize as many passive means as possible as a primary design objective. “The most obvious justification for the bio-climatic approach to the skyscraper is the lowering of life-cycle financial and energy costs.” [3] Viewing these items as design drivers verses add-ons is a key component for success, which reiterates the directive for form finding verses unrelated, form making. Another directive beyond the site and program selection processes mentioned earlier, was a variable approach to façade treatment, which would relate to prevailing wind conditions, sun paths and site conditions in general.

One student, Matt Propst chose to analyse the façade variation (or lack thereof) of the existing infrastructure in Phoenix, Arizona, USA. His hypothesis was that high performance ‘green’ buildings must be the new standard, yet the heart of the problem lies with our buildings that have already been built. As of 2003, existing buildings in the United States numbered 4.9 million, while new building projects totalled just 57,000. New building construction each year only adds roughly 1 percent to the U.S. building stock. Matt argued that the focus must be put back on our existing buildings to have an impact. Using Autodesk’s software, ‘Ecotect’ he analysed the lack of façade variation in an existing four block, high-rise Phoenix neighbourhood (Fig. 5).

The United States Desert Southwest has some of the highest levels of solar radiation in the country with Arizona having more than 300 days of sun a year. Matt recognized the huge potential for solar power and designed a prosthetic system that would implement solar technologies into the existing buildings and infrastructure. This would allow for the opportunity to make the current inefficient buildings efficient. It also created shade for facades and outdoor circulation spaces, while creating energy to put back into the grid. This prosthetic system, built on urban buildings, was designed to take advantage of its location. Diagrammatically, inefficiency equalled opportunity; the more densely the system was incorporated into that building. The result became a symbiotic relationship where existing architecture both allowed for and benefited from the solar collectors. This application also meant that the energy was created in urban areas where it was most needed and that more natural areas could be left intact that otherwise may be utilized for large scale solar arrays. Water to cool the system was collected and stored from rainfall and building condensate from cooling systems.

Analysis of natural light and air movement were also important passive design drivers, encouraging a healthier interior environment. This could be accomplished in multiple ways: by smaller floor plates, opening up cores or floors to light and landscaping or pulling the building apart to open it up (Fig. 6).

Structure, skin and circulation are key design components of high-rise design. Following the biomimetic trajectory students experimented with structural form finding from tension-based systems.
An assignment was created to study digital and analog methods of form-finding for tension-based structures (Fig. 7). There was also a desire in some students to explore minimal surface form finding akin to much of the natural world. These studies became hybrids of analog and digital testing, using the latest parametric plug-ins, with physics engines to assist with this form finding process.

CONCLUSION
Relation-based aspects of parametric computer modelling programs are closer to the information-based processing in nature. With anything, though, it is important to remember that it is not just valid because one is using some contemporary technology. We need to move beyond this to be critical of the inputs and how they relate to a knowledge-based design aesthetic that is appropriate on many levels. We also have a long way to go computationally. Live analytical feedback loops via parametric software are continuously developing, but are still relatively complex and clunky. We need to make sure we are not simplifying our algorithms, though, due to this complexity or we will never improve our built environments. Ideally we need to simulate these dynamic systems real-time, factoring in as many issues as possible, including life-cycle and social costs.

Some groups were able to combine more analysis tools than others. BIM is about information, but also ideally, about using this information in a smart way, the 4th dimension using time and energy. This interface is crucial if we are to move beyond the green-washing that is the current general state of affairs and incorporate these principles in the earlier design stages.

The projects would have been more developed in a traditional architectural sense if there had been a more prescriptive pedagogical model with regards to the site and program. However there were so many unexpected, relevant topics that were enthusiastically generated by students, which made it seem like it was the right decision. This is not necessarily an ideal model for every studio in the curriculum, but seems valid for at least one of the student’s learning opportunities. The feedback post semester reaffirmed this. The studio ended up being more of a brainstorming experiment that addressed multiple issues. Finding this balance between bottom-up versus top down pedagogical models is continually a challenge, but generally the learning environment is enhanced with the ability for everyone to be creative and to learn from each other.

How far do we need to adjust our current trajectory in order to be truly sustainable? Apart from just creating alternative energy in abundance don’t we need to learn how to design and live more efficiently? As William McDonough has stated “being less bad is not good.” [4]

REFERENCES
BIBLIOGRAPHY