Architecture and Resilience on the Human Scale

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Learning Comprehensive Building Design through a Resilience Framework

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ABSTRACT A framework for building resilience is critical to contemporary architecture practice, which is challenged to design buildings now that will first shape and then sustain a dramatically different and uncertain future. This framework is both a conceptual structure to define and organize characteristics of buildings as adaptive systems across physical and time scales (resilience as outcome), as well as a practical guide to organize design decisions and strategies that lead to specific solutions (resilience as a process). Students need this framework—both the theory and its real-life application—to learn ways design mitigates harm, nourishes life, and adapts to a changing world. Merging a lecture course with a design studio creates a cohesive pedagogy around problems of resilience, and provides critical context to the teaching of Comprehensive Building Design. The course Integrated Building Systems interrogates texts and case studies around issues of resilience to engage critically with conventions of design and construction, systems thinking, and ecology. The Comprehensive Design Studio uses real sites, integrated design and interdisciplinary collaboration to provoke the critical application of resilience principles and elicit design solutions for a complex environment of uncertainty and change. This framework reverses the traditional studio sequence, beginning with building systems rather than a program or a site, and emphasizing life-cycle sensitive design. Four phases overtly organize systems and design decisions from the more to less permanent, constantly shifting physical and time scales: from passive systems, to ecosystems, scenario-planning, and ultimately the synthesis and detailing of assemblies. Learning comprehensive building design through an ecological resilience framework emphasizes passive and structural solutions as the means to flexibility, durability, climate adaptation, reduced environmental impact, ecological integration, and human comfort.

KEYWORDS: Resilience, buildings, systems, integration, pedagogy, comprehensive.

Introduction

The potential of ecological resilience as a metaphor for building systems is best understood through the work of ecologist C.S. Holling, who differentiated stability, namely the “ability of a system to return to an equilibrium state after a temporary disturbance,” from resilience, which provides “a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships.” (Holling, 1973) This distinction, namely “shifting emphasis from the equilibrium states to the conditions of persistence,” is critical to understand that while engineering resilience is associated with stability expected of designed systems, ecological resilience is associated with dynamic
living systems. As optimization-driven design fields become increasingly aware of the dependence of designed systems on a dynamic and unpredictable environment, they find ecological resilience a useful framework. This is especially true in architecture, which in the last century has proved neither stable nor resilient, becoming increasingly vulnerable to the effects of ecological deterioration and an ever more commodified environment, indeed the "subject of short-term investment, income-generation, and resale, rather than life-long dwelling or long-term city making." (Benedikt, 1999) A renewed focus on sustainable development and ecological restoration emphasizes designing long-life buildings as elements of dynamic urban ecologies, and requires balancing optimization with robustness, durability with adaptability. This is a provocative mandate for practice, one Holling might describe as the "interplay of stabilizing and destabilizing properties", between "two contrasting aspects of stability: efficiency of function and existence of function." (Holling, 1996).

Given this mandate, a critical intellectual framework for building resilience must acknowledge that buildings are embedded in coupled social and ecological systems, which are "sufficiently complex that our knowledge of them, and our ability to predict their future dynamics, will never be complete." (Berkes, 2007) As educators and researchers, we are interested in resilience as a framework for "understanding how to sustain and enhance the adaptive capacity in a complex world of rapid transformations" (Folke et al., 2002) and we believe that we must engage architecture students in finding design solutions to these vital issues of sustainability and resilience. There are two premises to a resilience framework in architecture: first is the ambition that sustainable buildings—specifically their functions of shelter and delight—should last a long time to justify the investment of ecological resources; and the second is the risk that overly optimized buildings leave communities vulnerable to changing social and ecological conditions. This seeming contradiction captures the importance of learning to think critically about both the enduring qualities of well-designed buildings, and about the assumptions made in designing them.

To promote that critical thinking, we developed a theoretical framework for building resilience that applies ecological resilience principles to study the design of buildings and landscapes as adaptive systems. Because resilience is both process and outcome (Ayyub, 2014), we propose that a framework for building resilience is both a conceptual structure to define characteristics of buildings and landscapes across physical and time scales (outcomes), as shown on Table 1, as well as a practical guide to organize design decisions and strategies that lead to specific solutions for building resilience (process). Because ecological resilience is multi-scalar, it requires a systems perspective for design: including building components, building sites, districts, cities, and beyond. Thus resilience is not only a
critical topic for designers and students, it is a way of framing the broader issues of comprehensive building design.

The capstone course of the Architecture curriculum, the Comprehensive Design Studio, is the ideal place to implement this model. Unlike other studios that focus on specific skills, this studio challenges students at the end of their studies to integrate and synthesize their acquired knowledge into a comprehensively designed building and site. Students identify attributes that make buildings more likely to persist and adapt in the face of an uncertain future, and seek ways that each building can improve the resilience of its community. The studio is structured to engage systems thinking, to challenge traditional design processes, and to encourage investigations on form, materiality and performance.

Characteristics of the Framework

Resilience works across spatio-temporal scales. Resilient buildings must withstand short-term disturbances and maintain function, (engineering resilience of individual components) and persist in long-term trends (ecological resilience of complex adaptive systems). (Martin-Breen and Anderies, 2011) Tierney's model of resilience, originally developed for seismic risk, provides a framework of Robustness, Redundancy, Resourcefulness and Rapidity, for resilience across different time scales. (Tierney, 2007) The same model identifies four domains of resilience Technical, Organizational, Social, and Economic (TOSE), which operate at multiple physical scales. While architecture often remains within the realm of the Technical, a critical practice must also understand how buildings engage other domains of resilience, as illustrated in Table 1.

Robustness: beyond shelter

The literature suggests that building codes focus on structural integrity and safety, rather than on continuity of function; suggesting resilient buildings as those exceeding minimum code requirements so that key building systems continue to function. (Jennings et al., 2013) This framework for ecological resilience not only investigates parameters to maintain functional and life-safety in short-term events, but also considers the qualities of long-life buildings that can sustain human comfort in multiple futures.

Redundancy: multiple paths to maintain function

Because resilience is the ability to maintain function in different conditions, the redundancy and diversity of systems improve outcomes in cases of failure. In this framework a main driver of design for building resilience is provision of multiple, integrated and adaptable ways to provide function (e.g. active and passive).
Rapidity: resourcefulness for response and recovery

Steward Brand argued for an “evolutionary design”, influenced by changes in ecology and economics from “equilibrium-based” to “variance-driven” systems. (Brand, 1994) Optimizing buildings as singular responses finely tuned to program, site, and technology results in design “locked-into” particular pathways. The danger of a locked-in pathway is that “only a massive or radical shock or stress is enough to motivate path-breaking behaviours and changes.” (Pendall et al., 2010, p. 75) This framework delays program, to prioritize comfort and delight, climate response and adaptability, and ecosystem services as drivers. It provides a life-cycle perspective to the design of buildings: considering design decisions from the more permanent (orientation, site, primary structure) to the less permanent (technology, weathering elements). It is critical to consider the effects of climate on materials, the environmental demands of future uses and populations, and future technological and social changes. A framework for building resilience needs to better engage the theory of impermanence (Ford, 1997), by designing for serviceability and weathering in buildings, engaging economic factors of material durability and designing “the proportion of larger, more permanent elements and smaller, replaceable parts” (Mostafavi, 1993).

Renewal: The theory of reality and the reality of theory

Critical of conventional practice that renounces theory, which “simply reiterates unstated theoretical assumptions” (Allen, 2000) we combined courses on theory and practice, a model typically seen in Science, in the teaching of what is otherwise pragmatic and technology-centered Comprehensive Building Design. The lecture course, similar to a natural history or ecology class, presents empirical knowledge, theories based on observations of the natural and built environment. The studio works as a laboratory for exploratory learning, in which students apply theoretical principles, experience the process of discovery, and document results to be evaluated by peers. In the Integrated Building Systems lecture, students explore theory and modes of practice that engage critically with conventions of construction, systems thinking, and ecology. The goal is learning how to combine critical theory and practice towards what Stan Allen proposed as “a notion of practice flexible enough to engage the complexity of the real, yet sufficiently secure in its own technical and conceptual bases to go beyond the simple reflection of the real.”
Table 1. Framework connecting the domains and timescales of resilience.

**Resilience in the Classroom and Studio**

We applied and tested this framework over the past two years in the Comprehensive Design Studio. As a capstone course, this studio draws on the full-range of students’ architectural knowledge to satisfy accreditation requirements for the integrated design of a building and its requisite systems. We engaged *resilience* as both a topic worthy of study, and as a method to teach the other content in this course. Learning comprehensive building design through an ecological resilience framework emphasizes passive and structural solutions as the means to durability, adaptability, ecological integration and restoration, and human comfort. This significantly changes both teaching and learning.

**Course Structure**

The semester is divided into four approximately month-long phases; in phase one students develop structural parameters for passive building systems based on a given
climate. During phase two students are given a specific site for which they research the ecology, human history, infrastructure, and future human intentions across many scales of time and space. Using that understanding—and still without a building program—students develop buildings that emerge from and are grounded in the current and future site and infrastructure, rather than simply on them. In phase three, students methodically address uncertainty by using scenario planning to design the building (and constituent systems) for multiple future uses and contexts. In the final phase four, students develop the assembly of their projects to a high level of detail: ensuring a comprehensive design with both breadth and depth.

Perhaps no other change is met with more curiosity and questions than the decision to essentially reverse the sequence of the studio, so that rather than a program or a site, it begins with building systems; their performance and relative permanence. When students approach buildings systematically, the structural, envelope, comfort, site, and other building systems are generative, and drive the initial formal and functional parameters of the design. Over the course of the semester, each additional element of design—site, program, material, or detail—is introduced as a system itself, and a part of the overall project’s “system of systems”. Thus rather than any one element of the project becoming deterministic, or forcing students to optimize the design for one set of conditions, each new element offers new components of the ecosystem, and also new connections to the existing elements.

Each phase of the studio not only steps towards a fully-developed project; it focuses on specific course content (e.g. site and landscape design, MEP systems) while connecting the design effort a particular aspect of the resilience framework (e.g. future programmatic flexibility). We provoke these investigations with specific learning activities and teaching approaches. The result is an integrated pedagogy for integrated design, as illustrated below.

**Systems As Focus**

In the first phase, students adopt a set of strategies for three major building systems: structure (e.g. load-bearing masonry, steel frame), enclosure (insulated panels, curtainwall) and comfort, and look for ways to integrate those systems into a resilient building. For buildings, ecological resilience is of course metaphorical (Pendall et al., 2010), but the idea of preserving relationships in the face of change is quite applicable in the design of buildings, because it encourages students to think of buildings as the integration of physical systems to achieve performative (but not necessarily physical) ends. We encourage students to think about these relationships as parameters, for example, there is a geometric relationship between the physical dimension (height) of a window and the penetration of useful daylight for a visual task, while there is a material relationship between the construction of a wall and its thermal resistance. Students identify the parametric
relationships inherent to these systems, and the possibilities for and limitations on the spatial, structural and environmental performance criteria. This approach deliberately foregrounds the longest-lived parts of buildings, like structure, in the face those that might be fleeting, the occupants and their furnishings. If we consider buildings as systems of systems (and embedded in larger systems of site and infrastructure) the integration of sometimes the complex reciprocal relationships between building systems and building performance over time presents the fundamental task of resilience.

Site investigations across time and physical scales

In the second phase, students are given a specific site. Buildings link to a whole ecosystem of the built and natural world, so the first task is site research across many scales. These investigations are often rich in their own right, and fruitful generators of form. Students discover that urban buildings are not self-sufficient islands but depend on a network of urban systems, and in turn those buildings shape resilient communities, now and in the future, a deeply ecological understanding, based on the notion of dynamic equilibrium, not stability. Students design such that the site becomes an integral system to the building, and the building become integral to and transformative of its topographical, climatological, ecological, cultural, and physical context now and in the future.

The Future-Buffered Building

The third phase of the studio introduces a host of possible programs that might occur over the life of a building. While it is impossible to predict the future, as architects our students will be asked to plan for it; and those designs will meet current and anticipate possible subsequent uses and conditions. To address the uncertainty, we introduce the tool of scenario planning to the students, who undertake a self-facilitated exercise as a group, with some faculty guidance on process and data, but growing out of their deep understanding of the site and forces. Structured scenarios have been identified as useful tools for resilience-building by “envisioning alternative futures and the pathways by which they might be reached” as well as identifying “actions that might attain or avoid particular outcomes.” (Folke et al., 2002) Because the resilient building is about what it does, not what it is, scenario-planning leads students to a series of possible futures for the building, and an approach to flexibility that allows their buildings to thrive in each of those future states.

Students must design buildings that can transform efficiently to meet unknown future spatial, structural, and energy needs, and in response to a changing context and environment. These future uses are often developed spatially (i.e. the contents fit in the building) but must also work systematically (e.g. structural and thermal loads, integration
with comfort systems, appropriate fenestration). As the uses and layouts become ever more real, students refine the active systems (which use energy to overcome the limitations of the passive parameters). The goal by the end of this phase is that students have a design that successfully integrates building use and building systems for multiple possible futures.

*Using skills to merge theory and reality*

The Comprehensive Design Studio is about understanding architecture’s *physical* manifestation: buildings built in space out of real materials and subject to real forces of physics, chemistry and biology over time. Throughout both courses, we invite guest experts to provide “reality” as well as subject matter content, from details of integrating structure or HVAC systems, to the possibilities of prefabricated façade systems, and the integration of building and site water management systems. Similarly, resilient design is both a technical and cultural proposition, grounded in the real world and highly relevant to, and reliant on, the world of practice. Drawing on many practitioners from diverse disciplines as critics and consultants, and working on vulnerable local sites, prepares students for new modes of practice in complex environments of uncertainty and change. Emphasizing collaboration, students work in pairs, and each pair will have at least three consultations with experts like structural and mechanical engineers, envelope consultants, and landscape architects. The confrontation of the real world of a specific site, of proper details, of durable and reparable systems, informs—and in some cases constrains—the design.

*Conclusions and Future Work*

The quality of coursework and anecdotal feedback from students and guest critics suggest that a Building Resilience framework is a successful model for teaching comprehensive design. The next step is a systematic learning-science study of student outcomes of this approach, and to measure the impact of resilience education on practice after graduation. We are engaged with colleagues from landscape architecture and engineering to explore ways the resilience pedagogy might enhance integrate the capstone experiences in the various disciplines.

The continued refinement of the resilience framework through coursework serves as an important testbed for new resilience metrics being developed by the authors support from our home institution, the National Science Foundation, and from industry. While these metrics ultimately serve practice, they first grow and develop in classrooms, just as practitioners do: as part of a critical pedagogy to shape and sustain those who will design our future world.
References


