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Re-Structuring Practice for Sustainability: Learning from Case Studies

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Abstract

One of the biggest challenges in professional education today is to re-structure paradigms of practice to achieve higher-performing buildings and more livable communities. While great progress is being made in building performance research, there is often a great gap between research and practice. This paper is based on the idea that the typical highly resource-consuming development widely practiced today is a symptom of a deeper problem, which is an ineffective design process. To create sustainable buildings or communities, students and practitioners need a better model for incorporating empirical information into design. Three case studies in sustainable design can offer insights into the kind of design process needed to turn theories of sustainability into reality.

1 Introduction

A lot of research is going into improving building technologies to reduce energy consumption, carbon emissions, or waste products (Loftness, 2004). But this progress in building science research is far ahead of what is being practiced in the field (Vischer and Zeisel, 2008). Even without the challenge of climate change, buildings account for a great share of resources and affect people's lives and poor design decisions have negative impacts for many years…can't afford wrong decisions (Sroufe et al, 2019).

Building science research is widely published and available (Straube, 2012). Software tools are advancing the capacity to simulate and predict the consequences of design decisions. One major reason that we are not seeing the widespread improvements that such research makes possible is that the conventional project development process itself divorces decision-making from the knowledge needed to inform those decisions (Bobbe et al, 2016). It is linear and siloed.

The integrated design process (IDP) is widely advocated as the primary means to achieving high performance design goals by organizations such as the American Institute of Architects, the US Green Building Council, the National Institute of Building Sciences, and comparable organizations in Europe and Canada (Koch and Henrik, 2013). The shortcomings of the conventional design process derive from the fact that early decisions by architect and client, which are also the most impactful, are made without the benefit of engineers and other specialists, who are brought into the project much later. "There is a limited possibility of optimization during the traditional process, while optimization in the later stages of the process is often troublesome or even impossible." (Larsson, 2005).

More specifically, the characteristics of the conventional design process that hinder the creation of innovative and sustainable buildings are:

- Linearity: the expectation that problems can be solved one at a time—first the architectural concept, then engineering systems (Trumpf et al, 2007). In the conventional linear process, engineers are required to retrofit the building design with building systems. Just as problematically, most engineers are not prepared to engage in an iterative process, which costs more time than a one-time solution.
- Silos: specializations in education and business model. Each specialized consultant works within a defined framework of established and unchallenged "givens", which prevents holistic thinking and the breakthroughs such thinking makes possible.
- Ill-defined goals: Owners and architects who have great aspirations but only a general idea of goals often default to certification standards or "best practices" rather than devoting the effort to establish quantitative targets. Without such targets, the design team has neither guidance nor accountability.
- Reliance on mechanical equipment (and mechanistic thinking): Most design and engineering professionals in the field today are better educated in mechanical systems than in utilizing natural processes. Specialization, which narrows the definition of problems, tends to reinforce mechanistic models of thought (Hjorth & Bagheri, 2006).
- Construction cost estimating disconnected from the process: In conventional design, cost estimating is not undertaken until a substantial amount of design work has been done. Like other specialists, cost estimators appreciate having as much detail to work with as possible, but their input is so late in the process that the only way to reconcile the project with the budget is to cut out scope, which means performance. Moreover, in conventional design process, consideration is given only to first-time construction costs, not long-term operations costs or return on investment.

In an integrated process for sustainable design, a digital simulation of building performance is created early and used as a guide for iterative design schemes: a design proposal is generated, its performance (eg, energy consumption or air infiltration) is tested by modeling it, and the cost to build it is determined with a detailed construction cost estimate. With the benefit of concurrent simulations and cost estimates, passive strategies are fully explored before active strategies are considered. The reduced demand for energy achieved with passive strategies is directly responsible for savings in reduced active (mechanical) systems. At each point in the process, the design team can see how their proposal compares to the project's targets, and the owner can see the value of each improvement in performance. With iterative cycles of designing, modeling, and costing of the envelope/MEP systems, the team is able to align their design strategies to meet the owner's goals.

This paper examines three projects with ambitious sustainability goals. Each of the three projects grew out of a strong commitment to sustainability. Among other goals, they aspired to a high-performance building that would require far less energy and produce much less carbon than what is typically built today. Each project has its own goals, drivers, and challenges, but they all demonstrate the critical role that re-structuring the design process plays in turning theoretical possibilities into actual realities.

Case Study 1: East Liberty Presbyterian Church

East Liberty Presbyterian Church (ELPC) in Pittsburgh, Pennsylvania, was built in the 1930s in the Gothic style, a signature building of the renowned architect Ralph Adams Cram. The building is heated by its original steam boiler system, which was typically run continuously for six to seven months each year. Increasingly warm summers and the lack of air conditioning meant that summer programming had to be limited to avoid using the warmest areas in the building. Moreover, the church realized that even without improving comfort, the cost of operating such a large building would consume an increasing proportion of its resources, leaving less in the future to serving the community. In 2014, ELPC began planning the church building's first comprehensive renovation, with the intention of becoming better stewards of its built and natural resources. The project goals included better use of space with enhanced comfort, improved energy performance, and water conservation, along with meeting current code requirements.

The church hired its design team with the stated goal of improving the sustainability of the building, but project initially took a traditional approach to design and construction. The first schematic design ended up with construction costs that were double the intended budget of $6 million, excessive operating expenses, and uncertainty about the effectiveness of the proposed cooling system. The leadership at ELPC recognized that the only way to meet its project goals was to reassess its traditional approach to design and construction.

So instead of undertaking the expected value engineering and moving on to design development, ELPC invested in a whole-building performance model, a detailed digital simulation, to understand how the existing building was functioning. Digital meters and both interior and exterior sensors were installed. Whole building blower-door tests were run, and a thorough inventory and life-cycle assessment of all active mechanical systems was made. With this empirical evidence, ELPC created a comprehensive Owner's Performance Report to define the project goals and targets. The report gave the team specific tangible information, and together the building performance specialists, design team, and client were able to use the model in an iterative and collaborative process. By pinpointing the sources of energy consumption, the team was prepared to restructure the process in accordance with the "natural order of sustainability" (Mazria, 1979), passive first, active second, renewable last.

The most difficult challenge was to make the building more comfortable during hot weather. Everyone was surprised by the discovery that Ralph Adams Cram had designed a sophisticated natural ventilation system for the building, which had not been used for decades. Secondly, it was determined that the thermal lag of the building's mass could be used to provide greater cooling by bringing in nighttime air. In addition, a mock-up of summertime conditions demonstrated that a combination of dehumidification and air movement strategies would be sufficient to bring the building into the comfort range.

The project had many passive strategies, despite the limitations of historic design, including repairing the original windows, adding weathertight gaskets, and installing new glass-door airlocks at building entrances. The subsequent active strategies included uncoupling ventilation from cooling, adding a dedicated outdoor air system (DOAS) system to provide filtered and dehumidified fresh air, installing a new building management system to control all active systems, scheduling nighttime purge ventilation to take advantage of free cooling, and creating an energy-management platform and dashboard to measure and monitor whole-building energy use and indoor air quality.

Through this alternative process, the team produced a final design that was within the project budget, met the goal of using 30–40 percent less energy than in pre-construction performance, and provided superior indoor air quality throughout the entire church building. ELPC completed construction at the end of 2018, and the current energy trends are well within the predicted performance targets.

ELPC is using its smart building infrastructure to continuously improve overall building performance. While this is not yet a Zero-Energy building, the approach taken by the project team sets ELPC up for the addition of renewable energy sources. By reaching the church's energy goals through the combination of passive and active strategies, ELPC has in place the most cost-effective path possible to reach Zero-Energy with future production of renewable energy. Lastly, in December of 2018, ELPC became the first church in the world to achieve RESET Air Certification for Interiors.

Case Study 2: Mycelia Development Cultural Arts Center

Mycelia Development is a small but forward-thinking organization headquartered in Beaver Falls, PA, an underserved community that has not recovered from losing its major industrial employers in the 1980s. The name, Mycelia, references the "root structure of mushrooms", which are "always committed to the benefit of the host environment". Mycelia Development set out to invigorate the economically depressed community with a beautiful, high-performance building (appropriately named the "Portobello" building), providing a space for visual and performing arts, events, and farm-to-table food.

From the outset, Mycelia Development's Portobello Building was envisioned as a change agent for its employees, the town, and the region, as well as a robust example of sustainable building practices. Despite the energy intensity of ceramic kilns, café equipment and theatrical lighting, the owner's aspirations included net zero energy, superior indoor air quality, low-embodied energy materials, and balanced storm water management with zero outflow from the site. Portobello set out to use Passive House (PH) principles with the intention of obtaining certification under the Green Building Initiative's Green Globes system (a requirement for funding), RESET Air, and Fitwel.

What happened is the story of a well-intentioned owner whose team was only superficially committed and modestly prepared to deliver on the ambitious vision of a transformative project. While the groundwork was laid for an integrated empirically based design process, the team soon fell back into the more familiar and traditional siloed process, and their decisions were not aligned to the project goals.

Mycelia began the development project by retaining an owner's representative, experienced in LEED checklists but with little experience in that role. In 2018, Mycelia terminated its first architect, as it had become clear to the owners that this project team was not serious about pursuing the project's sustainability goals. Mycelia then engaged a second architect and the AUROS Group to work with their original engineering team.

The AUROS Group's first step was to engage the project team in a Discovery Charrette, where Mycelia's goals were quantified as specific targets and recorded as the Owner's Project Requirements (OPR). This critical step paved the way for accomplishing the ambitious project the team envisioned. The OPR was modified and improved over the next 5 months, but the team failed to appreciate that to achieve aspirational building performance goals requires teams to integrate their work early in planning.

The second step was to produce a whole-building performance model along with a base construction estimate. The modeling report and cost estimate were shared with the owner, architect, engineers, and contractor. However, instead of using the information to revise the design, the team chose to pursue their initial proposal. It became apparent that the architect was committed to a dramatic design idea for the building and feared that it would be compromised by attempts to improve the performance of the building envelope. Adding to the problem, the mechanical engineer was unwilling to adjust or detail the narrative produced in the conceptual design phase and so were unable to address the OPR goals. Neither the owner nor owner's representative intervened to redirect the design process.

It is important to note that, based on experience in other recent projects, the first round of simulation indicated that the project was within reach of meeting both the OPR targets and the owner's budget of $4.4 million. While it required design modifications, the kinds of changes needed were achievable and could be accomplished without significant increases in cost. In this case, however, the design team chose to pursue a traditional path, which also deprived the owner of any basis for questioning the contractor's ever-increasing prices.

In short, as the project is moving into the final phase before construction, the owner has abandoned the OPR, reverted back to building code-based standards, and is focused on meeting only the lowest requirements for Green Globes certification. Performance simulations have been disconnected from design decision-making, and those decisions have been made without the benefit of performance analysis. The project construction budget, which began at $4.4 million, is now reportedly over $5.5 million, while nearly all the high-performance project goals have been sacrificed. The schedule has been pushed back 12 months. At its final completion, the project is not likely to achieve much beyond code compliance.

Case Study 3: Belleview Neighborhood

Belleview, a new compact neighborhood in a small western city, is also intended to be a model of sustainable design. It is envisioned as a diverse neighborhood where families at various income levels, stages of life, sizes, and backgrounds can afford to purchase a home. The town has been experiencing nearly thirty years of unprecedented growth, mostly suburban sprawl. Population growth has fueled fast-paced increase in real estate values, which in turn has created an affordability crisis. Today, this is most acutely felt by households in low-paying jobs, including municipal service workers. A successful compact neighborhood might open the door to more affordable housing and more sustainable patterns of development. Climate change is contributing to extreme temperatures: more severe winters and hotter dryer summers. The harsher weather in recent years is driving up monthly utility bills, making affordability an issue of long-term operations as much as initial purchase price.

The new neighborhood features 60 housing units on an eight-acre site. They range from an 800 square foot one-bedroom cottage to a 1500 square foot three-bedroom gable-front house. All housing types have generous front porches and modest private yards. The houses are intended to minimize their environmental footprint by compact site and building design and their highly insulated, well-sealed building envelope. The design team was committed from the outset to a performance-oriented design process. Based on the natural order of sustainability, the building designs first incorporated passive strategies. In addition to their compact shape, most are attached with shared party walls to reduce exposure to outdoor weather. Projecting eaves and deep porch roofs help shelter interior spaces from overheating. Outdoor spaces, such as the three common courtyards, are sheltered with trees, fences, and building walls.

Iterative modeling simulated the hygrothermic behavior of the envelope, guiding the design process from the outset. One significant finding from the initial model was that building orientation was not a major factor in performance due to the highly insulated and strategically shaded building envelope. A preliminary estimate of construction cost was done along with the energy model, as the design team was well aware that the developer could not sacrifice affordability for optimal performance. While the developer had not given the design team a construction budget, the anticipated cost per square foot was in line with recent housing construction in the area.

The site and housing design, informed by the results of the modeling, used strategies that the team knew were both energy-conserving and cost-effective. Even in early design, the houses incorporated features such as thick walls and carefully placed windows which would be essential to meeting performance goals.

Meanwhile, the developer had determined that the project would be designed and built to meet PH standards, which had been shown to reduce energy demand by as much as 90% with as little as a 3% increase in construction cost. The design team was confident that the project was on track to meet or exceed those goals, based on prior experience with PH design.

Upon submission of the project to the city for approval, the management of the design process shifted from the lead design firm to the local associated firm, which had been involved in the design process from the outset. Several complications made this transition challenging. First, the local architects were less prepared to lead a collaborative and iterative process than the developer thought. Because of inexperience with high-performance housing, they were reluctant to adopt unfamiliar building details, particularly since they understood how critical small leakages could be. They were inclined instead to look for high-performing materials that would allow them to retain as much conventional construction as possible. They were also worried that the cost of PH design would far exceed what was projected, and the developer had still not committed to a construction budget. Secondly, the general contracting firm, which was brought onto the team at this time, was supportive of the concept of higher performance but equally inexperienced in PH construction. Their initial cost estimate, which was based on preliminary design development documents and prior to any training in PH construction, added in a 50% premium. The third factor was a sustainability consultant who convinced the owner to defer the next round of energy modeling in favor of following what were described as best practices, unrelated to any specific performance goals. The consultant also introduced the idea that the primary sustainability goal should be to maximize the use of low-carbon materials in construction, including two products manufactured in and imported from Europe.

What was clearly missing at this point was a set of specific performance targets that would have guided design decisions, facilitated the completion of the design development documents, and provided a well-defined basis for costing. The design team was trying to sort out conflicting priorities from owner, sustainability consultant, and contractor, which resulted in a kind of paralysis. If the process had continued on track, the design development documents based on a second iteration of energy modeling would have been completed in six to eight weeks while the contractor's team was being educated in PH construction to prepare them to produce a more reasonable cost estimate. Instead, the project schedule has suffered a six-month delay and the contractor's cost estimate interrupted further progress until a radical cost reduction could be achieved.

It is possible for this project to get back on track, but while everyone on the team is well-intentioned and believes in the vision of the project, the team suffers from a lack of confidence in the power of a performance-oriented design process to guide decision-making to an environmentally-sound, financially viable, contextually appropriate, and marketable outcome. Falling back onto "best practices" has led to discussions that disintegrate into competing conflicting ideas about how to proceed. They not only exhaust the team but convey the impression that designing for sustainability is even harder to accomplish than they had anticipated.

This experience is not unique. It highlights the pitfalls of trying to accomplish high-performance design by a team—even a committed and collaborative team—that isn't prepared to restructure the conventional process of design and development.

Conclusion: Lessons Learned

While each of the three project teams encountered unanticipated difficulties in reaching their sustainability goals, they have taken important steps beyond conventional practice and more importantly, have had an opportunity to learn from those experiences. The purpose of the case studies is not just to highlight the kinds of difficulties encountered in designing high-performance buildings, but to identify opportunities for practicing professionals to sidestep some common pitfalls and for researchers to focus on areas for fruitful investigation. As case studies, these projects enabled us to discern a number of patterns that seem to be worth further investigation. We note here two kinds of lessons learned: first, a sequence of key steps in re-structuring the design process and second, a set of proposed requisites for producing a successful high-performance project.

Key Steps

Step 1: Set metric based goals and targets. Then build the team based on a performance-based engagement process and assign the proper responsibilities and accountabilities to achieve the goals.

Step 2. Organize an integrated and iterative process, including modeling and estimating. High-performance building design is a process of successive approximation aimed at meeting the project goals, including quantitative targets. It is essential to break down the "hand-off" design process. Implement early conceptual whole-building sustainability modeling and cost estimating processes that inform iterative design decisions.

Step 3. Set up the design process using the Natural Order of Sustainability. Start with passive strategies: use the non-mechanical architectural elements to lessen the need for energy, which in turn reduces the size and operating cost of mechanical equipment. To accommodate this much-reduced demand most efficiently, decouple heating, cooling, and ventilating systems and introduce heat and moisture recovery. Use energy-efficient equipment and lighting. Finally, add renewable energy generation.

Step 4: Connect quality assurance/quality control field testing and commissioning to the key performance indicators of design. Critically, the "right sizing" of mechanical systems is directly related to the performance of the envelope. A high-performance building is dependent upon the performance of the thermal barrier, air barrier, building envelope, and mechanical and electrical systems. They must be tested to ensure whole-building performance.

Step 5: Evaluate success based on long-term outcomes, not just design. Give the building a measurement and verification system connected to the key performance indicators of design and create feedback loops that track actual building performance and compare it to the design targets. A connected measurement and verification system ensures high-performance operation of the building.

Requisites for creating a high-performing project:

- The owner/client understands the value of a high-performance building and is prepared to achieve it.
- The team is experienced in high-performance building is engaged to work collaboratively from the outset: architect, engineers, building performance consultant, contractor, facilities operator.
- Contract documents for design team define an iterative process and expected level of participation, including generating and testing of multiple alternatives
- Well-defined performance goals are established by team at outset of project (OPR). Budget and other parameters are included.
- The team is held accountable to performance requirements throughout design and construction.
- The OPR drives the choice of sustainability programs, rather than vice versa.
- The team carries out the design process according to the natural order of sustainability: passive first, active second, and renewables last.

- The team evaluates costs associated with any level of performance to determine the best value both in short term and long term. The team's design decisions reflect that evaluation. (While most architects and contractors have the general knowledge to price construction projects, few can demonstrate their design's specific return on investment by doing a cost vs. energy analysis.)
- The team is committed to open, full exchange of information, including open book budget and costing.
- The team displays good leadership and teamwork-habits, including authentic commitment to stated goals, effective communication, timely execution of tasks, and respectful management of conflict.

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