AIA

THE AMERICAN INSTITUTE OF ARCHITECTS

2005 Report on University Research

It is said that a journey of a thousand miles begins with a single step. In many ways, this document is just that, a first step. As the AIA continues towards its goal of becoming a more knowledgeable organization, it is imperative that we place increased emphasis on research. Specifically, we need to place this emphasis on research that we can apply to practice.

From our first discussions about a knowledge-based organization in 2001—and from the first AIA Knowledge Summit in San Diego in 2002—it became clear that the profession needed to deepen its investment in research. Much the way medicine revolutionized practice in the early 1900s by increasing its emphasis on research, we hope that by better understanding the physical and sociological aspects of the built environment we can spark comparable change within our profession. From fluid dynamics to child development, research informs the design of better environments.

To best plan for new research, however, we need to first understand the depth and breadth of current research activities in the field. Several significant initiatives are already in place—the AIA College of Fellow's Latrobe Fellowship, for example, which helped create of the Academy of Neuroscience for Architecture; and the exemplary grant program of the Boston Society of Architects, which has supported dozens of new research projects. In order to better understand and document the current research activity in advanced professional education, the AIA's Board Knowledge Committee issued a request for proposals to all universities in the fall 2004. Our goal was to gather, highlight, and distribute reports on research that ultimately may serve to advance professional knowledge and practice.

As a pilot program, we aim to sample exemplary research, stimulate interest and discussion among the AIA's emerging knowledge communities, and develop and refine a process that will strengthen the relationship between the profession and the universities.

The schedule for this project was aggressive. The RFP went out in November of 2004. Even with the short deadline, the AIA received 28 proposals from 14 universities in 11 states, including one submission from the US Department of Education. In the end, the jury awarded 10 grants of $4,000 each so that the authors could prepare their contributions for this report.

In this report you will find a wide range of topics covering a variety of methodologies. You can explore the makings of a design guide for daycare facilities for patients with dementia; or you can learn about the development of a software program used to help owners evaluate building investments and make more informed long-term decisions. There are also reports on web-based collaboration, tools for navigating evidence based design, and a study on a building strategy for converting obsolete office buildings to housing.

Intended as an informal but substantive and dynamic publication, this report serves to set the tone of future programs by illustrating the potential benefits of research for our profession. Read it, digest it, and respond to it. The long road ahead begins with a single step; we look forward to having you join us for the rest of the journey—a journey practice and education can only make together.

Shannon Kraus, AIA, Chair
AIA Board Knowledge Committee
2005 AIA Vice President

March 2005

BoKnoCo@aia.org

BUILDING INVESTMENT DECISION SUPPORT (BIDS™)

Cost-Benefit Tool to Promote High Performance Components, Flexible Infrastructures and Systems Integration for Sustainable Commercial Buildings and Productive Organizations

Vivian Loftness FAIA, Volker Hartkopf PhD
Beran Gurtekin PhD
Ying Hua, Ming Qu, Megan Snyder, Yun Gu,
Xiaodi Yang Graduate Students
Carnegie Mellon University Center for Building Performance and Diagnostics

Given the growing demand for sustainable buildings by federal and private sector clients, professional practices are "tooling up" all over the world to deliver high performance, environmentally responsive, "green" buildings. However, investments in sustainable, high performance building solutions and technologies are still limited by first cost decision-making, and life cycle tools are still largely inaccessible to professionals. A new building investment decision support tool—BIDS™—has been developed by the NSF/IUCRC Center for Building Performance (CBPD) at Carnegie Mellon University, with the support of the Advanced Building Systems Integration Consor-tium (ABSIC).[1] This cost-benefit decision support tool presents the results of over 150 life cycle data from field case studies, laboratory studies, simulation studies, and other research efforts. The substantial environ-mental cost-benefits of a range of advanced and innovative building systems, to deliver—privacy and interaction, ergonomics, lighting control, thermal control, network flexibility, and access to the natural environment—can now be quantified by professionals. This tool supports professionals in building life cycle justifications for high performance/green design innovations, and illustrates the amazing return on investments possible, through a range of cost-benefits—from the "immediate dollars" of energy efficiency, waste management, and churn, to the "long term dollars" of improved indoor environmental quality, productivity, and health. Environmental design principles and life-cycle decision making are critical to our professional commitment to improving quality of life.

MITIGATING THE EFFECTS OF HURRICANES IN FLORIDA: THE CHALLENGES OF UPGRADING MOBILE HOME PARKS

Stephen Schreiber FAIA
Associate Professor
University of South Florida
School of Architecture and Community Design

This report focuses on state and local barriers to upgrading mobile homes and communities in west central Florida (with a focus on Polk County). This work involved interviews with mobile home owners and renters, mobile home park owners or managers, mobile home manufacturers or agents, architects, engineers, building and planning officials, as well as visits to several mobile home parks. Additionally, the team conducted extensive research of existing local land-use laws, codes, plans and regulations; surveyed building officials and mobile home dealers to determine the extent of knowledge gaps with respect to regulatory environment regarding mobile homes. The importance of this research was made obvious by the 2004 hurricane season, in which four major storms created significant damage to Florida's housing stock, particularly mobile homes.

SHARING TACIT DESIGN KNOWLEDGE IN A DISTRIBUTED DESIGN ENVIRONMENT

Jeong-Han Woo, Mark Clayton, Robert Johnson
Benito Flores, Chris Ellis
Texas A&M

Tacit knowledge is highly personal and implicit. As such, it encompasses expertise, intuitive understanding, and professional insight formed as a result of experience. Throughout the life cycle of a design project, architects rely heavily on their tacit design knowledge to support design decisions. Due to its implicit nature, tacit design knowledge is typically shared only among colleagues who work in the same office through face-to-face interactions. With emerging CMC (Computer-Mediated Communication) technologies, architectural design process faces new opportunities for capturing and reusing tacit design knowledge. However, there is no accepted and guaranteed CMC strategy for sharing tacit design knowledge in the AEC industry.

This research investigates the impact of tacit design knowledge that was captured and shared using online, interactive chat-based software developed by the researchers. The software was tested in a graduate-level architectural design studio in which design students sought advice from experts in remote locations.

Content analysis of comments from the experts provides qualitative evidence for the software's effectiveness. Participants shared past experiences, professional recommendations, and intuitive expectations. The chat sessions also included the identification, clarification, and explanation of real problems. Dialogue records provide evidence of a noticeable influence upon the students' approach to conceptual design. In follow-up surveys, most participants reported that their experience with the software was very enjoyable and the software is well-designed to support sharing of design knowledge.

This research also suggests that tacit design knowledge may be confidently captured and shared through careful strategic implementation in a distributed design environment. Demographic and attitudinal surveys of the participants suggest that enabling factors for sharing tacit design knowledge include knowledge sharing attitude, strong top-down management support, just-in-time expertise matching, CMC technologies support, and a higher sense of cohesion. Strong management support and commitment from leadership can provide direction for knowledge sharing strategy.

INFORMATION VISUALIZATION DESIGN: THE GROWING CHALLENGES OF A DATA SATURATED WORLD

Jim Agutter
College of Architecture + Planning
University of Utah

The Information Visualization Design project is an eight year long, interdisciplinary research effort in expanding the creative boundaries of Architectural Practice.

As our civilization continues to dive deeper into the information age, making sense of complex data becomes critical. Information visualization responds to this challenge by using architectural expertise to solve information interpretation problems facing many fields. The result is the design, construction, testing, and deployment of data environments supporting real time decision making in Medical, Finance, Process Control, Live Performance, and Network Monitoring. These information spaces take advantage of the vast and innate human perceptual abilities in pattern finding. Rigorous scientific testing has demonstrated that 'dwelling' in such data architectures allows people to make more accurate, faster, and better decisions while reducing cognitive load and stress.

This work also demonstrates the natural leadership role that architecture may play in interdisciplinary endeavors. Using core architectural competencies, two architecture faculty became the leaders of a collaborative assembly of five interdisciplinary teams with over 25 individuals.

The success of this research has been proven by its longevity, over $4.7M in grants, over 50 articles published across four fields, several pending patents, a spin-off company, three commercial licenses, and over 20 live public performances. In recognition of their cutting edge work Julio Bermudez and Jim Agutter have been awarded the Association of Collegiate Schools of Architecture (ACSA) 2004-2005 Creative Achievement Award. Such accomplishments challenge conventional views of architectural practice and provide students, faculty and practitioners exciting opportunities to create digital information spaces

DESIGN GUIDELINES FOR ADULT DAY SERVICES

Keith Diaz Moore PhD, AIA
Washington State University

This article is a synopsis of a book entitled *Designing a Better Day* (forthcoming, Johns Hopkins University Press). Its purpose is to provide to provide a practical overview of recommendations for the design of adult day service facilities developed through a multi-method research process occurring over the past six years. The project started by asking what is the current state of design in adult day services and followed up by asking what should the state of the art be in order for adult day services to achieve their tremendous therapeutic potential? The methodology followed to answer these questions included literature review, case studies involving both observational and dialogical data, the use of theoretical extrapolations and empirical findings to inform the recommendations and a dialogical process seeking to produce consensual understanding. Concepts presented include an overview of adult day services as it is and how it came to be, a core set of "realms of activity" that any designer needs to carefully witness and understand in order to engage in such a design effort; a way of conceptualizing adult day services as a place, and a highlighted set of design recommendations that are well-reasoned "best guesses" as to how such facilities could be designed to further their therapeutic intent.

AN OPEN BUILDING STRATEGY FOR CONVERTING OBSOLETE OFFICE BUILDINGS TO HOUSING

Stephen Kendall PhD
Director, Building Futures Institute
Ball State University

New real estate investment strategies are needed to support the increasing numbers of American families who will be drawn to live in urban areas in the next decades. These strategies must be supported by new design, logistics and construction methods, the subject of this research. One new strategy we studied in depth would produce a new stock of "open buildings" both newly built and converted from obsolete office buildings. The principle arguments of this paper are, therefore, that (1) methods are available to adapt our building stock to the natural dynamics of society with less conflict and waste than our current practices enable; (2) that our building stock need not be designed for fixed, specific income classes or household structures, but should accommodate both change and variety, and (3) that our building industry processes—in design, logistics, construction and long term asset management—can learn to balance supply and demand more effectively. This report therefore focuses on architectural, technical, and logistical methods in respect to these three points. This includes outlining methods to harness the building industry to meet individual household preferences. Decisions concerning each dwelling—its space layout, equipment, piping, wiring, and ductwork—must be disentangled from the decisions concerning what is shared in a given building, the common spatial and technical infrastructure. This paper outlines principles and practical methods of achieving an "open architecture"; it uses as a case study the conversion of an obsolete Detroit office building to housing.

CONTENT ANALYSIS OF WEB-BASED COLLABORATIVE DESIGN: EMPIRICAL EVIDENCE OF DESIGN PROCESS

Eberhard Laepple,[1] Mark Clayton,[1]
Robert Johnson,[1] Steve Parshall[2]
[1] CRS Center, Texas A&M University, College Station TX
[2] HOK Advance Strategies, Houston, TX

Web-Based Communication Systems (WBCS) are project specific web sites that provide dedicated web hosted "collaboration and information spaces" for the AEC industry to support design, engineering and construction teams. These systems have an underlying software structure that is shared for many independent building projects. A typical system provides controlled access to the project data from any physical location through the Internet. WBCS can have various features, such as email, message board, document repos-itory, calendar functions, to-do-lists, and project administrative features.

The software itself is not new; it has already been applied in architecture and even more in engineering. Current studies indicate that there are over 260 WBCS available on the market (Orr 2004). However, many architects are hesitant to use the new technology and are not convinced of its potential. The concern firms share is that a WBCS may waste time or fail to enable a successful project (Laiserin 2002). The question is: do WBCS tools contribute effectively to building projects?

Current research has investigated several limited aspects of Web-based communication. Previous studies have generally dealt with data from an experimental setting or are single case studies. The objective of this study is to measure the use of WBCS within AEC. This study employs a new approach in AEC research by using data produced as a byproduct of the commercial use of design support software.

BEYOND NET-TO-GROSS: ANALOG TOOLS FOR THINKING WITH NON-ARCHITECTS ABOUT THE DESIGN OF CIRCULATION AND OTHER SHARED SPACES

Jamie Horwitz PhD
Iowa State University

Among the challenges facing contemporary architects today is a growing public interest in evidence-based design. As recently reported in the AIA Journal evidence-based design is a "rigorous, hypothesis-testing" approach to design practice that builds on a literature of user-oriented building evaluation research (post-occupancy evaluation research or POEs).[1] Bringing the authority of scientific method into design practice, we are told, will be the next qualifying standard among firms.[2]

A designer's desire to lend the authority of science to the art and pragmatics of building is understandable. So are a client's desire for greater accountability and less uncertainty when selecting an architect, establishing a budget, negotiating a design, and most of all, deciding to invest in facilities rather than in people or services. Everyone wants to decrease his or her exposure.

Design conventions that evolve through iterative refinement and empirical evaluation are likely to be better—and any approach that welcomes research into design practice is promising—for society, for the environment, and for a person like me who is likely to find more room at the table. Yet, the idea that science trumps architecture troubles me. In the multivalent context of design decision-making, I fear the results of a process in which architectural thought could be effaced in the name of 'evidence'.

As firms reflect on contemporary challenges and opportunities, some are questioning conventional models of practice in a knowledge-oriented service economy.[3] The inter-relationship of design, research and strategic services is leading some architects to recast their firms into an 'ideas company' in which professional practice can lead or follow client-centered consulting contracts.[4] Whether or not models of practice change, today more and different types of expertise participate in all levels of design decisions. Will the new mix of services make for better buildings, better cities, and better environments? I believe that depends not only on bringing new knowledge into design decisions; better environments depend on bringing the inherently integrative thinking of architecture into design decisions that are, all too often, made without architects.

A COMPREHENSIVE APPROACH TO TEACHING STRUCTURES USING MULTIMEDIA

Shahin Vassigh
University at Buffalo/SUNY

The project *A Comprehensive Approach to Teaching Structures Using Multimedia* was the outcome of a collaboration of an inter-institutional, multi-disciplinary team from the University at Buffalo, State University of New York; University of Oregon and University of Utah. The project aim was to create an environment for teaching and learning structures that facilitates the comprehension of fundamental principles, practical aspects of structural design, and the creative possibilities of applied structure within the built environment. The project began by a seed grant from the University at Buffalo in 1999 and was funded by the U.S. Department of Education, Fund for the Improvement of Postsecondary Education (FIPSE) from 2001 to 2004. The faculty team project included: Shahin Vassigh and Dr. Scott Danford from University at Buffalo, the State University of New York; Patrick Tripeny from University of Utah; Ronald Shaeffer from Florida A&M; Christine Theodoropoulos from University of Oregon; and Edward Allen.

GOLCONDE: THE INTRODUCTION OF MODERNISM IN INDIA

Pankaj Vir Gupta, AIA
Christine Mueller
University of Texas at Austin

As contemporary architectural practice has sought to cope with the demands of an increasingly global society, architects are confronting the dilemma of proposing design solutions in unfamiliar cultural and geographic contexts. All too often, the international nature of contemporary practice compels an accelerated schedule of client meetings, site visits, and design proposals, all on unfamiliar cultural and geographic terrain. The results of this type of engagement seldom result in an architecture capable of assimilating the nuances of site, local identity, and technology.

Our research has focused on an exemplary work of early modernist architecture in India, designed by two pioneers of the modernist movement. Working within a cross-cultural platform, they built one of the earliest works of sustainable modern architecture in the world. It predates the more renowned, modernist essays by Le Corbusier in Chandigarh (1951–64) and Ahmedabad (1952–56), and pioneers the use of reinforced concrete construction in India. Completed in 1945, the building—a dormitory for a spiritual community—espouses the virtue of radical economy and uncompromising construction standards. It proposes a mode of architectural practice where issues of technology and environment dictate the conception and tenor of the entire design process.

BUILDING INVESTMENT DECISION SUPPORT (BIDS™)

Cost-Benefit Tool to Promote High Performance Components, Flexible Infrastructures and Systems Integration for Sustainable Commercial Buildings and Productive Organizations

Vivian Loftness FAIA[1], Volker Hartkopf PhD,[2] Beran Gurtekin PhD[3]
Ying Hua, Ming Qu, Megan Snyder, Yun Gu, Xiaodi Yang Graduate Students

Carnegie Mellon University Center for Building Performance and Diagnostics

[1] Professor, School of Architecture, Carnegie Mellon University, Pittsburgh, PA
[2] Professor & Director, Center for Building Performance & Diagnostics, Carnegie Mellon
[3] Researcher, Center for Building Performance and Diagnostics, Carnegie Mellon

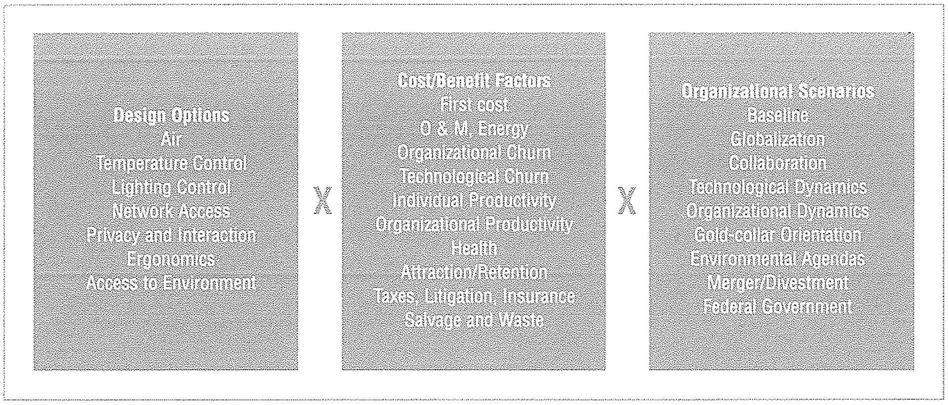


Figure 1. The Three Dimensions of the CBPD BIDS™/ EVA Matrix

1. Move beyond broad definitions of sustainability to justify high performance materials and assemblies.

Investment in high-performance, sustainable building design and technologies is limited by first-cost decision-making. In our collective enthusiasm to define and promote sustainability, we may be making two fundamental errors: first, broad "motherhood" definitions of sustainability, and second, arguments that green design need not cost more.

Environmental designers often argue for broad sustainability objectives without further detail, as expressed in the AIA/UIA declaration of Interdependence for a Sustainable Future "Sustainable design integrates consideration of resource and energy efficiency, healthy buildings, ecologically and socially sensitive land-use, and an aesthetic sensitivity that inspires, affirms and ennobles." However, investors and clients will need to understand the specific quality differences of sustainable design alternatives—component by component—if they are to move beyond least-first-cost decisionmaking. Imagine selling only "mobility" with cars ranging from $10,000 to $30,000. Every 'investor' knows component by component the quality differences in the two cars, including life cycle benefits, and typically invests in the higher cost product to purchase performance qualities. Imagine selling only "computational capability" with laptops ranging from $1000 to $3000. Again, the computing industry has made quality differences in even the most hidden infrastructures in laptops evident to the customer, leading to higher quality purchases. The genius of LEED™ certification from the U.S. Green Building Council[2] is that it defines sustainability in 69 more defined goals, giving the client the opportunity to qualify a greater investment of expertise or capital in their buildings.

While promoting either broad or detailed sustainability goals, many sustainable building designers will simultaneously argue that 'green' design should not cost more. This has led to a number of national studies on the cost of green, from Greg Kats' "Cost and Benefits of Green Buildings"[3] to GSA's "LEED® Cost Study"[4]. These studies have demonstrated that modest 2-4 percent cost increases can achieve Silver and Gold level LEED certification, ensuring improvements for sustainability with short term cost paybacks. While invaluable arguments for introducing sustainability, these modest cost increases are locking architects and engineers out of true quality improvements in a wide range of building materials, components and systems that are critical to ensuring: indoor air quality, thermal control, lighting control, network access, privacy and interaction, ergonomics, and access to the natural environment. The cost of a high quality light fixture, for example, one with the most energy effective T-5 lamp, continuous dimming and daylight responsive ballast, high performance reflector and lens, and potentially even separate ambient uplighting and task downlight, might demand the 3 to 1 ratio of quality and cost typical in other industries, in order to replace the least cost components that are typically installed. It is imperative that life-cycle data sets and tools be developed to establish the cost-benefits of high performance building technologies– component by component. The Advanced Building Systems Integration Consortium (ABSIC), a consortium of industries and federal agencies, and the Center for Building Performance and Diagnostics (CBPD) continues a ten-year effort to define high-performance buildings to promote each component and system innovation that will enhance the quality of the individual workplace (figure 2).

CBPD/ABSIC Design Guidelines for High Performance Buildings 2004

Guidelines for High Performance Enclosure Systems
1. Maximize individual access to the natural environment
2. Maximize daylighting for task and ambient lighting
3. Maximize natural ventilation with mixed-mode conditioning
4. Minimize enclosure heat loss/heat gain
5. Design solar heat and glare control
6. Engineer load balancing and mean radiant temperature control
7. Engineer passive and active solar heating, cooling and power
8. Maximize enclosure integrity and material sustainability
9. Pursue innovative systems integration for environmental quality, resource conservation and health

Guidelines for High Performance HVAC
for thermal and air quality, resource conservation & environmental health.
1. Separate ventilation systems from thermal conditioning
2. Design for natural ventilation with mixed-mode conditioning
3. Provide task conditioning and individual control
4. Design for continuous change with plug and play HVAC & controls
5. Design architecture 'unplugged' for maximum efficiency and passive
6. Engineer load balancing
7. Engineer energy and material effective HVAC systems with 'energy cascades'
8. Create distributed, communicating, modifiable automation systems
9. Pursue innovative systems integration for environmental quality, resource conservation and health

Guidelines for High Performance Lighting
1. Provide Daylighting as a dominant light source
2. Separate task lighting from ambient lighting or design relocatable task-ambient systems.
3. Introduce indirect-direct lighting to support spatial dynamics without shadowing.
4. Maximize lighting quality with high performance luminaires.
5. Provide for reconfigurability with plug-and-play fixtures.
6. Design for continuous change in lighting zone size and advanced controls
7. Pursue innovative systems integration for environmental quality, resource conservation and health

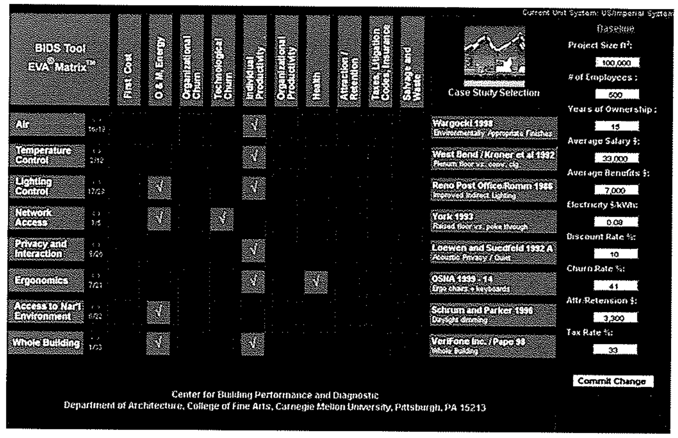
Guidelines for High Performance Connectivity
Networks for spatial flexibility, technological adaptability, and resource conservation.
1. Engineer independent plug-and-play networks—data/voice, power, security, and environmental services— with central communication
2. Design distributed cores for accessible, modifiable vertical distribution
3. Design distributed satellite closets with plug-and-play interfaces
4. Resolve integrated, reconfigurable plenum systems – ceiling or floor
5. Ensure user accessible, modifiable grid and nodes of services for connectivity
6. Create wiring harnesses for data/voice, power, security and environment
7. Select terminal units that provide all services—data, power, voice, security, environment—in reconfigurable boxes for just-in-time modifications
8. Create robust monitoring and individualized controls

Guidelines for High Performance Interior Systems
1. Design neighborhood clarity & shared spaces with flexibility
2. Design layers of ownership, multiple work environments
3. Ensure ergonomics/ functional support for shared work processes
4. Ensure ergonomics/functional support for individual work processes
5. Design "layers of closure," privacy and acoustic control
6. Design "layers of mobility" for workstations and workgroups
7. Provide levels of personalization
8. Ensure environmental infrastructure to support changing densities/ closure
9. Ensure technical infrastructure to support changing densities/ closure
10. Select interior system/components for material & energy conservation
11. Select healthy, maintainable interior components
12. Design for access to the natural environment

Design Process Changes for High Performance Buildings
? Involve full design team from the outset to ensure integrated design
? Develop Prototyped, Roll-out, Plug and Play Delivery of:
Air Quality, Thermal, Connectivity, Light, Interior Spaces
? Shift from Design-Build to Manufacture-Install for Life Cycle Value
? Shift to JIT Purchasing of Infrastructures for quality with cost control
? Establish Flexible Infrastructures for Dynamic Organizations

Figure 2. Guidelines to Improve the Quality of the Individual Workplace

The BIDS™ cost benefit analysis decision support tool



The Benefits of High Performance Buildings

1. **First Cost/Mortgage Savings through Quality Packages**
   Integrated System Savings over Individual Components
   Quality and Modularity with JIT Purchasing over Redundancy

2. **Facilities Management Cost Savings**
   Maintenance, Repair, Energy, Water, other Utilities, Cost of Discomfort, Failure costs, employee retention and training

3. **Individual Productivity Cost Savings:**
   (skill based, rule based, knowledge based jobs)
   Speed and Accuracy, Effectiveness, Creativity, Motivation, Absenteeism

4. **Organizational Productivity Cost Savings:**
   Profit, Time to Market, Customer Attraction and Retention, Recognition and Publicity, Continuous Work Flow, Real Estate Effectiveness, Team/Multi-disciplinary Creativity

5. **Attraction/ Retention or Turnover Cost Savings:**
   Time and Cost to Attract, Quality Attracted, Training Costs, Retention Rates

6. **Tax/Code/Insurance/ Litigation Cost-Savings**
   Utility & Tax Incentives, Tax Depreciation, Code Compliance, Insurance & Litigation Costs

7. **Health Cost Savings:**
   Workman's Compensation, Medical Insurance Costs, Health Litigation Costs, Environmental Evaluation & Remediation, Lost Work Time

8. **Spatial Renewability Cost Savings**
   Organizational Churn
   Labor and material costs for reconfiguring workstations and workgroups, hvac/lighting/networking system modification costs, occupant down-time

9. **Technological Renewability Cost Savings:**
   Technological Churn
   Networking: data/power/voice change, hardware/software change, training/mentoring costs, organizational/workspace and environmental/conditioning response costs

10. **Salvage/Waste Cost Savings**
    Organizational, Technological, Environmental Modifications, Activity related waste, Aging & Wear, Obsolescence, Salvage Value

Figure 3. The Broader Cost of Ownership

2. To justify high performance building components and systems, Understand the Cost of Ownership

In order to promote investment in sustainable, high quality buildings, it will be critical to prove to the client that the real cost of doing business is realized over time, not in first construction costs. Careful bookkeeping will reveal that "cheap" buildings and infrastructures, and "cheap" building delivery processes, result in major costs over time—energy costs, waste and renewal costs, productivity and health costs.

Moving beyond the "mantra" of individual productivity, the CBPD team has been researching the broader range of workplace-related expenses that are carried annually by organizations—from energy and facility management costs to churn and health and litigation costs. Most professionals know about the comparative advantage of productivity at $200/sq.ft./year, rent at $20/sq.ft./year and energy at $2/sq.ft./year. Yet productivity in the white collar workplace is hard to define and hard to measure, such that arguments for high performance, sustainable buildings may be more convincingly made with other annual expenses carried by the organization. The Carnegie Mellon BIDS™ research team has identified a list of ten cost-benefit areas where annual organizational investment is significant and could be reduced through a commitment to higher quality buildings (figure 3).

Figure 4. Cost of Doing Business

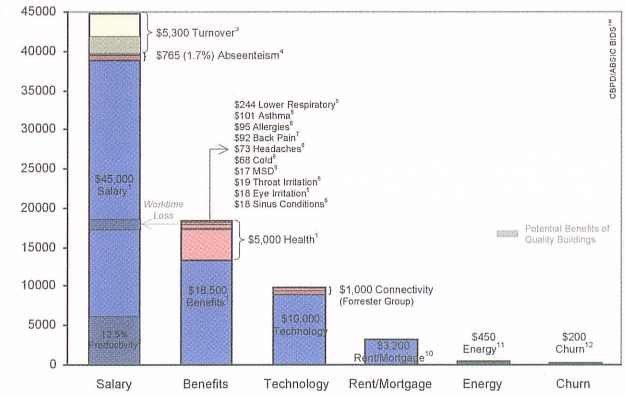


Figure 4 illustrates the strength of the data that the Center for Building Performance at Carnegie Mellon has been able to assemble on the cost of doing business that might be critically linked to the quality and sustainability of building components. The following sections will outline the baseline data for five of the ten cost-benefit arenas that the BIDS™ team continues to research, data that should help professionals "build the life cycle case" for high performance buildings.

2.1 Facilities Management Cost Savings

Maintenance, Repair, Energy, Water, Other Utilities, Cost of Discomfort, Employee Retention and Training, Failure Costs.

High performance buildings have the potential to generate significant operational cost savings, ranging from energy and other utility efficiencies, to facility management effectiveness, to the potential to reduce failure costs and measurable lost work time due to system failures. 25–50 percent energy savings, for example, can be achieved in most existing buildings and in sustainable approaches to new and construction. Since energy costs are often well known by a building owner, substantial recommendations for energy efficient innovations are often seriously considered if payback is less than 1–3 years. Beyond this time frame, however, few decision-makers believe in the predictions of the cost of energy, or that they will still own the building and be accruing savings from the innovation. With state and utility incentives to reduce peak power demands, and corporate investments to ensure power reliability in a brown-out, additional financial resources are available to invest in high performance building materials, components and integrated systems.

Maintenance and repair cost savings are less successful at promoting higher quality building systems, because there are very incomplete records on causes of maintenance and repair costs (including manpower) or the benefits of different design/engineering solutions. At present, energy use is typically 1–2 percent of current plant value, and facility management/ maintenance and repair costs are typically 2–4 percent of current plant value indicating the importance of pinpointing the costs of discomfort and failure due to inadequate investments.[5]

2.2 Individual Productivity Cost Savings:

Speed and Accuracy, Effectiveness, Creativity, Motivation, Absenteeism

Since a majority of the cost of doing business is for salaries (as much as 60 percent), any innovation that will clearly increase productivity even by a small percent will quickly payback investments in quality products and systems. Excluding benefits, the average annual compensation or salary for workers is $45,000 in the private sector and $50,000 in the public sector, given 2002 Bureau of Labor Statistics.[6] Even 1 percent of productivity savings would yield over $4,500 per employee per year to justify improved investment in the quality of their workplace. Adrian Leaman in England estimates the potential impact for buildings on overall productivity as +12.5 percent (improved performance) and -17 percent (hampered performance), for an overall 30 percent change in worker performance in the best and worst buildings[7].

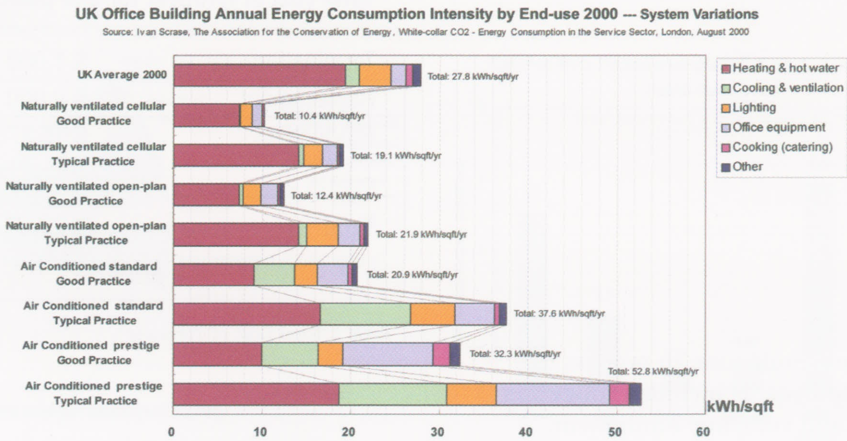


Figure 5. Annnual Energy Consumption Intensity of Office Building Types in U.K.

However, measuring productivity of the knowledge worker is very difficult, and must be studied differently for skill-based, rule-based and knowledge-based jobs.[8] While speed and accuracy may be easily tracked in skilled/manual jobs or even rule-based jobs such as call centers, knowledge-based work requires different measure-ment techniques to capture effectiveness at multiple tasks—both individual and collaborative. Creativity, motivation and focused attention, communication and collaborative output, as well as absenteeism and job impairment are meaningful but difficult indices to measure.

The two most readily available indices to evaluate investments in quality buildings are absenteeism (or unused sick days) and self assessment of productivity. In reference to absenteeism, the 2002 United States department of Labor's Current Population Survey[9] identified that private sector employees in the United States missed an average of 1.7 percent of scheduled work time. Given average weekly hours and salaries reported in the National Compen-sation Survey,[10] this amounts to 35 hours of missed work at a total cost of $756 annually. Absenteeism among public sector employees was slightly greater, at 2.2 percent or 42 hours, with an annual cost of $1,100. An additional indicator that could be explored is observed downtime for workplace modifications, complaints, and interruptions.

Some organizations have ongoing measures for worker performance that might include speed and accuracy (for example call center shipments), patents or products brought to market, and customer satisfaction. In controlled studies of white collar productivity, a battery of "knowledge based" tests, including simple, moderate and complex tasks, are used to evaluate the impact of workplace attributes on performance. These tests could include: seven number recall, phone book look-up speed, typing speed and accuracy, calculations, sentence completion, paragraph memorization, and creative thinking tests.

2.3 Attraction/ Retention or Turnover Cost Savings:

Time and Cost to Attract, Quality Attracted, Training Costs, Retention Rates

Another aspect of the productivity cost-benefit equation is the ability to attract and keep the best workers, the time needed for training, and the commitment of those workers to their work, including unpaid overtime. Average turnover rates for private professional positions is 20.3 percent with 6.8% rates for government positions.[11] A 2000 study by Jac Fitz-Enz identified four costs associated with employee turnover: termination, vacancy, replacement, and productivity loss.[12] The costs are calculated as follows:

Total cost of turnover for one position

Termination	$ 1,000
Replacement	$ 9,000
Productivity	$ 15,875 (3 months baseline salary and benefits)
Total - with 20.3% turnover rate	**$ 25,875** $ 5,300 per employee per year

Table 1. Total Cost of Turnover

1. **Termination**–Staff time to process the departing employee. It includes collecting badges, keys and company equipment, removing the departing employee from company payrolls and security lists, and processing any benefits extension programs. The typical cost of termination is $1,000 to $1,500 in staff time.

2. **Vacancy**–Assuming that all employees add value to the company or they would not be employed, a loss of revenue is incurred for every day a position is vacant. The cost of vacancy is the company revenue per employee per day multiplied by the number of days a position is vacant minus the cost of pay and benefits for the employee for those days.

3. **Replacement**–Cost of recruiting and inter-viewing candidates and processing and orientation for a new employee. The average cost is $1,100 for a non-exempt position, which is usually hourly waged and paid overtime, and $9,000 for a exempt position which is usually a salaried professional with no paid overtime.

4. **Productivity loss**–Due to a "learning curve," a new employee is rarely as productive as a departing one, so there is a decline in performance for some period of time until the new hire's productivity matches that of the former employee. The absolute minimum loss is the equivalent of three months' pay and benefits. For professional positions, this cost is likely to be much higher—up to one year's pay and benefits.

With average private sector turnover rates over 20%, the $5,000 lost per employee each year to the inability to attract or retain employees is a significant "cost center" for employers. In arguing for high performance, sustainable work environ-ments, it will be critical to establish the link between attracting and retaining the best employees and the quality the physical, environmental and technological workplace.

2.4 Health Cost Savings:

Workman's Compensation, Medical Insurance Costs, Health Litigation Costs, Environmental Evaluation & Remediation, Lost Work Time

After salary, the second major annual cost of an employee is benefits, including medical and insurance costs, as well as workman's compensation. Based on nine health insurance costs reported in five references, the BIDS™ baseline for employer health insurance cost is set at $5,000 per employee per year. Measured reductions in these costs would justify investment in better quality environments.

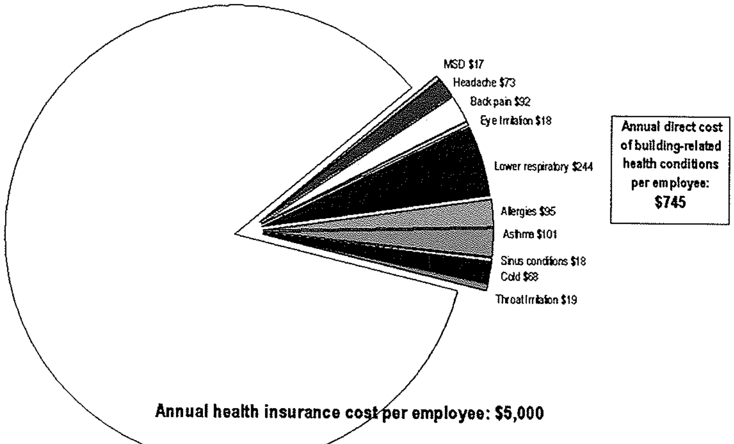


Figure 6. Annual Health Cost per Employee

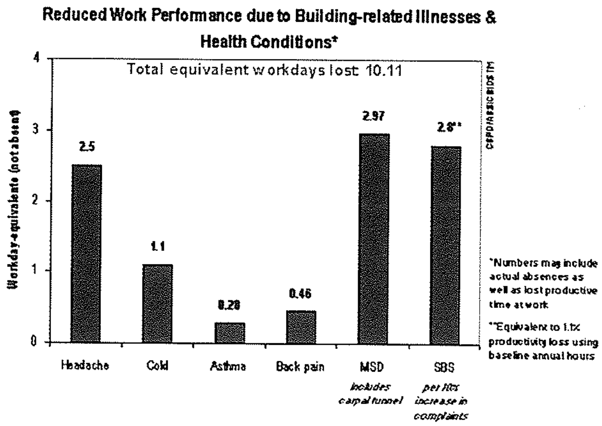


Figure 7. Lost Workdays Due to Building Related Illnesses

Given the CMU research to date, treatment for illnesses and health conditions that may be directly influenced by the indoor environment is costing employers $745 per employee annually, approximately 15 percent of all annual health insurance expenditures. Health conditions and illnesses that have been linked to the indoor environment include colds, headaches, respiratory illnesses, musculoskeletal disorders, back pain, and symptoms of Sick Building Syndrome (SBS).

The most easily identified health cost-savings linked to the quality of buildings are within workman's compensation, especially as related to muscular skeletal disorders (MSD). In the State of Washington, workers compensation claims for muscular skeletal disorders average over 43,000 per year with an average 1.84 workdays lost per employee.[13] Given average claim rates of 3.6 percent per workforce and median MSD cost of $470, the average MSD cost per employee per year is $17, which can be substantially offset (over 80 percent) through ergonomic furniture and employee training. The annual cost of muscular skeletal disorders may be only 'the tip of the building related iceberg', since the annual workman's compensation costs per employee exceeds over $500 per year according to the Bureau of Labor Statistics data.[14]

Beyond direct medical costs, researchers in the medical and occupational health fields have begun to identify the indirect costs of these health conditions to employers. As shown in figure 7, the indirect cost of productivity losses due to illnesses and health conditions may be even more significant than the direct costs for medical treatment. Not revealed in days absent, the indirect costs for health conditions are reflected in reduced effectiveness on the job, such as when an employee comes to work with a cold or continues working with a headache. The BIDS™ team has identified indirect (productivity-related) costs of several illnesses that are influenced by the indoor environment, including equivalent workdays lost due to colds, respiratory illnesses, musculoskeletal disorders, and Sick Building Syndrome (SBS).

One of the most dramatic health-related costs may be tied to "sick building syndrome" mitigation, including the direct and indirect health costs of employees, field study costs, remediation costs, litigation costs, and building down-time costs. Due to the fact that the many serious SBS cases have been settled out of court, findings that would lead to improving the workplace have not translated into greater investments in high performance design/engineering solutions.

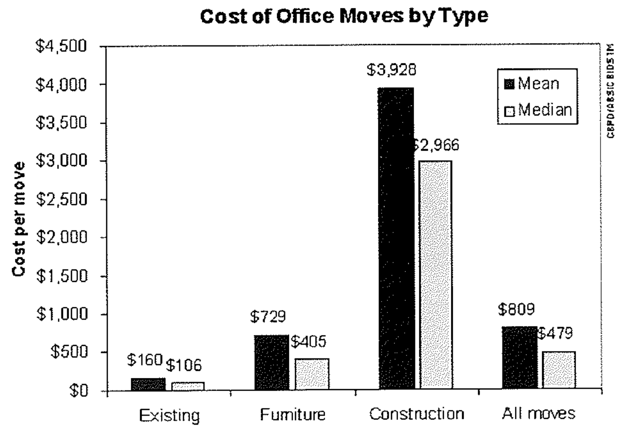


Figure 8. Cost of Office Moves by Type Based on IFMA Research Report 23, 2002

2.5 Spatial Renewability: Organizational Churn Cost Savings

Labor and material costs for reconfiguring workstations and workgroups, HVAC/Lighting/Networking System Modification Costs, Occupant Down-Time

There are significant cost-benefits to investing in renewable, quality building systems to reduce the cost of "churn". The International Facility Management Association (IFMA) has tracked churn rates for over a decade. From a survey of 291 companies in 2002, IFMA reports a mean churn rate of 41 percent for all types of facilties. IFMA classifies office moves in three categories: box moves, furniture moves, and construction moves. Given the diverse mix of types of moves in the 291 companies, the average cost per move was $809, while the median cost per move was $479[15]. These significant annual expenses are incurred to support the cost of: reconfiguring working groups and individual space; accommodating changes in functions, densities, and work hours; and accommodating rapid changes in technologies on the desktop.

Some organizations have been working to reduce space reconfiguration costs through universal footprints, shifting to "box moves" from one identical cubicle to another, especially in back offices. Other organizations are pursuing massive reconfigurations to support non-territorial offices, mobile workstations, micro workstations, and teaming spaces in response to organizational re-engineering. At the same time, occupant density, length of workday, and technology have dramatically increased in the workplace. As a result, system overload and failure costs are now accruing beyond the already significant costs of conventional churn. The extent of these organizational churn costs are not well documented, nor the benefits of investing in quality, "renewable" solutions, resulting in a lack of support for better life-cycle decision making.

3. BIDS™ — Linking quality building components to life cycle gains

Begun in 1999, the goal of the BIDS™ project at Carnegie Mellon University's School of Architecture has been to develop a cost-benefit analysis framework for advanced and innovative building systems and to incorporate these within a multimedia decision support tool. There have been four specific objectives set to achieve the goal:

1. The development of economic language and logic whereby intelligent workplace design can be thought of by the business investor as analogous to other emerging, strategically-central investments that have different operating life cycles (economic sustainability), competitive implications (workforce impacts), and payback periods (capital market valuation criteria).

2. The development of a cost-benefit analysis framework for evaluating various advanced and innovative building system options in relation to a range of cost-benefit or productivity studies, to be incorporated within a multi-media decision tool.

3. The determination of cost centers where the benefits of high-performance approaches will be significant and the expansion of a database relating quality indoor environments to major capital cost and benefit areas, including productivity, health, and operations costs.

4. The identification of laboratory and field case studies demonstrating the relationship of high-performance components, flexible infrastructures and systems integration to the range of cost-benefit or productivity indices.

Extensive review of the relevant literature to identify valuable case studies as well as related cost-benefit baseline data is a major part of this research project. The CMU BIDS™ team has been avidly pursuing case studies from around the world that link improved building environmental quality to life cycle cost-benefits. For each 1000 abstracts reviewed and 100 promising papers read, one case study with statisically significant data can be identified. With over five years of research attention, the BIDS™ tool now has over 150 case studies linking high performance building components and systems to life-cycle value.

4. Proof Sets in Hand

With the expansion of the case study database, the BIDS™ tool is beginning to have an adequate number of proofs to derive cross-sectional findings in relation to providing air, thermal control, lighting control, network access, and access to the natural environment for the individual workplace. With support from the Department of Energy, these cross-sectional findings enable us to convincingly argue for at least five critically important improvements in the quality of our buildings (http://cbpd.arc.cmu.edu/ebids).

4.1 Access to the Natural Environment: Daylight and Natural Ventilation

Over 10 percent of all U.S. energy use is in lighting buildings, much of this during the daytime when daylight is abundant. Add to this the 6 percent of all United States energy use spent cooling buildings summer and winter, and you have a significant argument for the environmental benefits of windows for daylighting and natural ventilation. Given the dominant number of existing buildings—schools, hospitals, offices, manufacturing facilities—originally designed for effective daylighting and natural ventilation, the erosion of natural conditioning is a serious energy cost to the nation.

Effective daylighting can yield 10-60 percent reductions in annual lighting energy consumption, with average energy savings for introducing daylight dimming technologies in existing building at over 30 percent.[16] Emerging mixed-mode HVAC systems that interactively support natural ventilation and air conditioning are demonstrating 40-75 percent reductions in annual HVAC energy consumption for cooling. Moreover, design for access to the natural environment, including daylighting and natural ventilation strategies, has shown measurable gains for productivity and health in the workplace.[17] The United States needs to meet European and Scandinavian standards that ensure that every worker is within 7 meters of a window wall, for views, light and air. The effective use of natural conditioning with well designed windows, window controls, and mechanical and lighting system interfaces, promises to yield major energy efficiency gains of up to 5 percent of all United States energy use, reduce risk in power outages, as well as provide measurable health and quality of life gains.

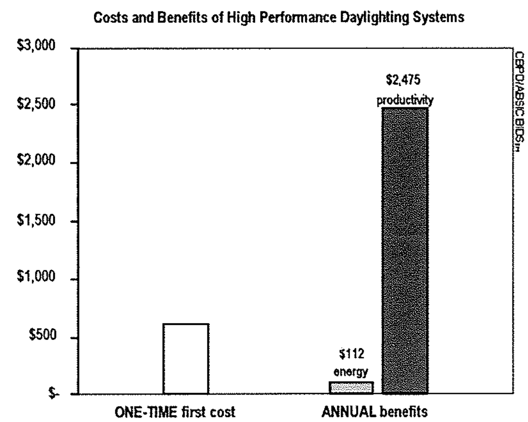


Figure 9. Cost and Benefits of Innovative Ligthing Systems (http://cbpd.arc.cmu.edu/ebids)

Daylighting Pays!

Maximize the use of daylight without glare and provide daylight-responsive lighting controls to ensure 22-60 percent overall energy savings, 35-65% lighting energy savings, and 0.45-40 percent productivity gains, for ROIs over 185 percent.

Eleven case studies have shown that innovative daylighting systems can pay for themselves in less than one year due to energy and productivity benefits. The BIDS™ tool demonstrates that daylighting yields annual energy cost savings of $112 per employee (~$1.00 per square foot) and annual productivity gains of $2,475 per employee, for total savings of up to $2,587 per employee annually. At one-time first cost premium of $600 per employee (~$3 per square foot in new construction), the ROI for an investment in daylighting is over 185 percent.

These conclusions have been built on three case studies indicating an average 44 percent reduction in overall energy consumption; six case studies indicating 52 percent average lighting energy savings due to high performance daylighting systems; and five case studies demonstrating individual productivity benefits from daylighting, with an average improvement of 5.5 percent annually. Finally, one case study written by Heschong Mahone Group[18] identifies a 40 percent improvement in organizational productivity due to daylighting, reflected in the increased retail sales in 72 daylit "big box" stores as compared to 36 stores without skylight.

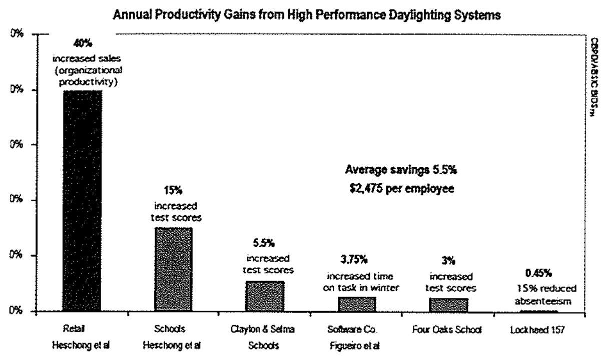


Figure 10. Productivity Benefits Associated with Daylighting (http://cbpd.arc.cmu.edu/ebids)

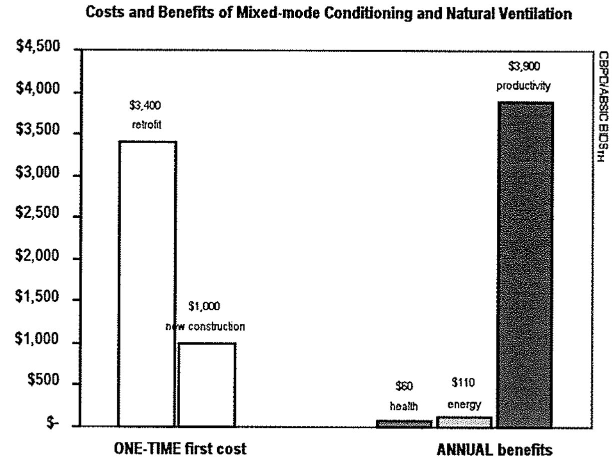


Figure 11. Cost and Benefits of Innovative Ligthing Systems (http://cbpd.arc.cmu.edu/ebids)

Natural Ventilation and Mixed Mode Conditioning Pays!

Replace or supplement mechanical ventilation with natural ventilation or mixed-mode conditioning to achieve 47-79 percent HVAC energy savings, 0.8-1.3 percent health cost savings, and 3-18 percent productivity gains, for an average ROI of at least 120 percent.

At the same time, eight case studies have shown that natural ventilation and mixed-mode systems can pay for themselves in less than one year due to energy and productivity benefits. The BIDS™ tool demonstrates that natural ventilation and mixed-mode systems yield annual energy cost savings of $110 per employee ($0.53 per square foot), health cost savings of $60 per employee, and annual productivity gains of $3,900 per employee, for a total savings of $4,070 per employee annually. With an estimated first cost premium of $1,000 per employee ($5 per square foot) in new construction and a documented first cost of $3,400 per employee ($17 per square foot) to modify an existing building, the average ROI for an investment in natural ventilation or mixed-mode conditioning is 407 percent for new construction and 120 percent for retrofits.

The BIDS™ team has identified three case studies that demonstrate HVAC energy savings due to mixed-mode conditioning or natural ventilation, with average savings of over 59 percent annually. Two case studies show health cost reductions, with an average savings of $60 per employee per year. Six case studies show individual productivity improvements due to mixed-mode or natural ventilation, with an average improvement of nearly 9 percent annually.

4.2 High Performance Equipment

The first trade-off in a value engineering excercise is typically to reduce the quality of the equipment and appliances that have been specified. Even short-term energy savings do not seem to be enough to drive decisionmakers towards quality. Either performance standards or links to productivity, health and other life cycle variables will be critical to promoting high performance equipment.

For example, the introduction of California and then national standards for equipment and appliance efficiency has had a major impact on national energy use, reducing overall energy consumption for heating, cooling and refrigeration by 25 percent, 40 percent and 75 percent respectively.[19] The direct relationship of appliance electricity demand and CO2 production illustrates the value of these energy savings in addressing climate change and reducing pollution from power plants. The impact of both R&D and standards has enabled refrigerator size and amenities to increase while overall energy use is reduced.[20] Four pending appliance standards (clothes washers, fluorescent light ballasts, water heaters and central air conditioners) are projected to save consumers $10 billion in unnecessary energy costs, improve functionality, and reduce cumulative emissions by as much as 80 Tg CO2 equivalent through 2010.[21] Given the natural replacement cycle of building appliances and equipment, 190 billion kWh of power demand can be eliminated by 2010 and another 130 billion kWh and .3Mbod can be eliminated by 2050 by just four building technologies—ballasts, lamps, windows, and refrigerator/freezers. There are few engineering obstacles and significant export growth potential in expanding appliance and equipment energy efficiency standards to cover the full range of existing and new equipment being introduced in residential and commercial buildings. Barring this commitment from the federal government or states, however, practitioners will need to use every life cycle value in their promotion of high performance technologies.

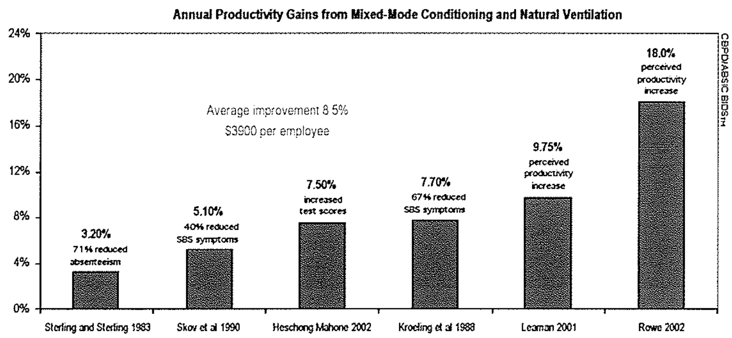


Figure 12 Productivity Benefits Associated with Natural Ventilation and Mixed-mode Conditioning (http://cbpd.arc.cmu.edu/ebids)

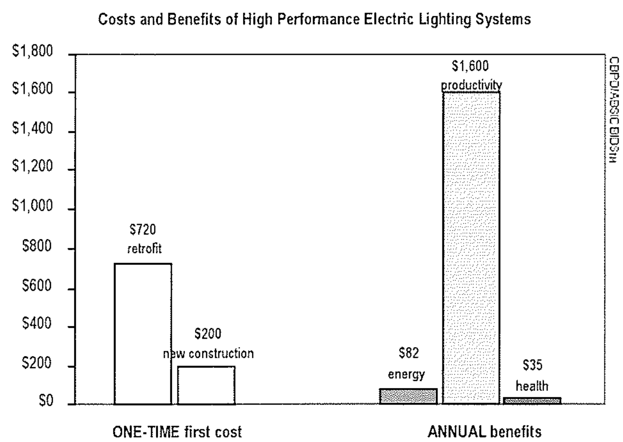


Figure 13. Costs and Benefits of High Performance Electric Lighting Systems. (http://cbpd.arc.cmu.edu/ebids)

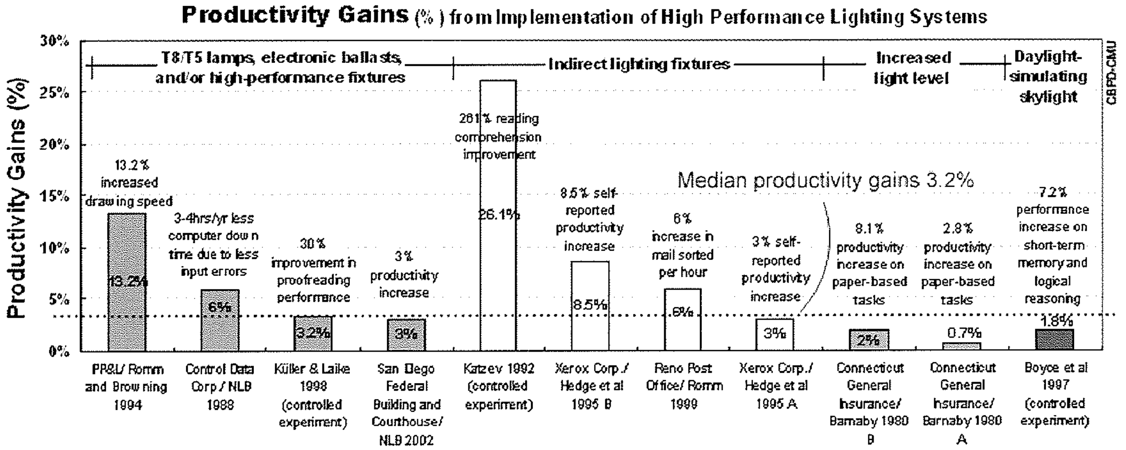


Figure 14. Productivity Benefits Associated with High Performance Lighting Systems (http://cbpd.arc.cmu.edu/ebids

High Performance Lighting Pays!

Replace outdated office lighting with quality electric lighting systems featuring high-performance lamps, ballasts, fixture and advanced controls for 27-87 percent lighting energy savings, 0.7-26 percent productivity gains, and 27 percent headache reduc-tion, with ROIs over 236 percent.

Twenty-five studies have helped to quantify the assertion that high performance lighting systems can pay for themselves in less than one year due to energy, productivity and health benefits. These studies demonstrate that daylighting yields annual energy cost savings of $82 per employee ($0.41 per square foot), annual productivity gains of $1,600 per employee, and annual health cost savings of $20 per employee, for total savings of up to $1,702 per employee annually. With a median first cost of $720 per employee for lighting retrofits ($3.60 per square foot, range of $0.63 to $7.45), and a median first cost increase of $200 per employee for high performance lighting systems in new construction ($1 per square foot, range $0.26 to $10.65), an investment in high performance electric lighting results in an ROI of 236 percent for retrofits and 851 percent for new construction.

Specifically, the BIDS™ has identified 15 case studies indicating a link between improved lighting design and annual lighting energy savings, with a median savings of 60 percent, or $79 per employee per year. Six case studies identify a link between improved lighting design and total annual energy savings, including lighting, cooling and associated HVAC energy consumption reductions, with a median savings of 18 percent, including an additional $3 to yield $82 per employee per year. The average lighting energy savings is 4.9 kWh per square foot annually, and the additional cooling energy savings averages 0.2 kWh per square foot per year. More financially signicant, however, nine case studies identify a link between improved lighting design and individual productivity gains, with a median improvement of 3.2 percent or $1,600 per employee per year. Across these studies, productivity is measured by improved working speed, reduced error rate, improved reading comprehension, improved short-term memory and logical reasoning, and by self-reported increases in productivity. Finally, a 1988 controlled experiment by Aars et al identifies a link between improved lighting design and 27 percent reduced incidence of headache, which accounts for 0.7 percent of overall employee health insurance cost or $35 per employee annually.[22]

4.3 Shading, Cool roofs and cool communities

Where once shading through massing, orientation, external and internal shading devices was integral with the aesthetics of place, the shading of buildings and communities today is a lost art. Again, first-least-cost decisionmaking will not support the dynamic and elegantly crafted solutions for shading that are invaluable to sustainable environments. Consequently, we must build the life-cycle proofs to support shading, landscaping and cool roof technologies, searching for energy, health, crime, maintenance and other benefits to promote investments in quality built environments.

Six percent of all United States electricity is used in cooling residential and commercial buildings,[23] at an annual cost of 40 billion, and peak power demands of 250 GW. A 5°F rise in neighborhood temper-atures—from excessive absorption of solar energy in our increasingly impervious built environment—increases cooling loads and raises the rate at which nitrogen oxides and VOC emissions from cars and smokestacks contribute to smog and ozone depletion. Indicative of many cities, Los Angeles now has over 10% impervious and highly absorptive surfaces in roads, parking lots and roofs. On a national level, the creation of "cool communities" with white roofs, pervious paving, and shade trees would yield a 10 percent reduction in annual cooling loads, and a 5 percent reduction in peak cooling loads.[24] Smog would drop by 6-8 percent and health related costs would be commensurately reduced. Moreover, local CO^2 would be sequestered by urban trees more effectively than an equivalent number of new 'forest' trees, and urban flooding would be reduced. Given the cycle time of roof replacements and tree growth rates, immediate federal and state policies and incentives are needed to realize the 2020 benefits of "cool communities" or architects and building owners will need to assemble convincing life-cycle data for cool roof technologies and cool community designs.

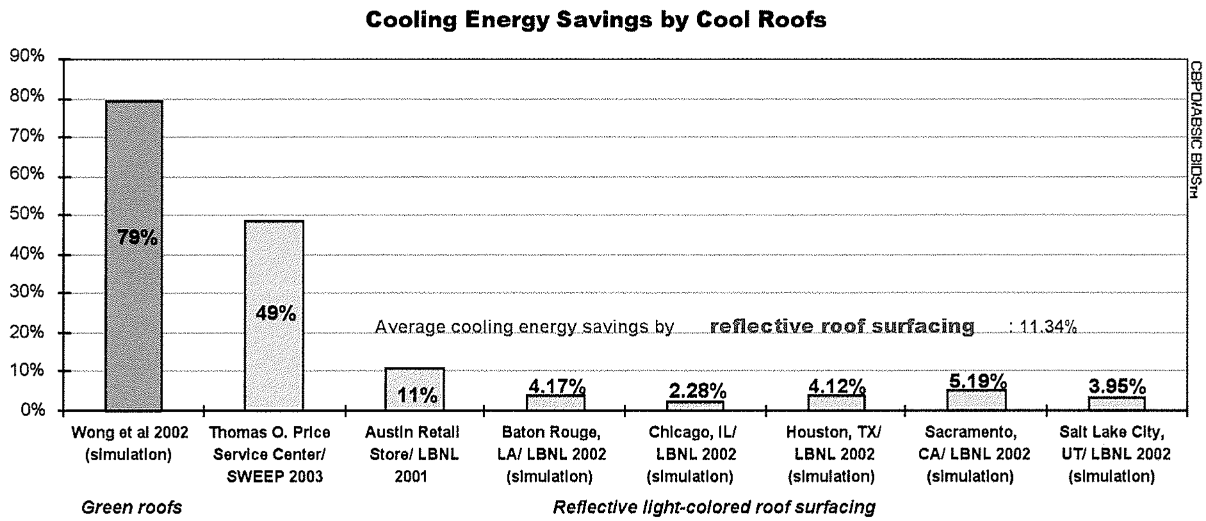


Figure 15. Cooling Energy Savings Associated with Cool Roofs (http://cbpd.arc.cmu.edu/ebids)

Cool Roofs Pay!

Replace conventional dark roofs with cool roofing for 2-79 percent cooling energy savings and 14-79 percent peak cooling demand reduction.

CMU's BIDS™ team has identified seven case studies indicating a link between reflective light-colored roofs and 2.3 percent to 49 percent reductions in annual cooling energy consumption, with an average savings of 11.3 percent or $0.02 per square foot. Reflective roofing has also been associated with an average peak cooling demand reduction of 14 percent. The average ROI for an investment in reflective roofing is 120 percent. Given the small price penalty for light colored roofs ($0.02/sq.ft. additional), the cooling energy savings can secure less than 1 to 5 year paybacks.

Although significantly more costly (at $6.5/sq.ft. average cost differential), 'extensive' (non-walk-able) green roof technologies are rapidly appearing in the United States From a series of energy simulations, Wong et al.[25] concludes that green roofs provide 48 percent average cooling energy savings (range 17– 79 percent), 8 percent average total energy savings (range 1– 15 percent), and an average 48 percent peak load reduction (range 17-79 percent). Based on this study, the optimum roof garden, composed of 300 mm thick soil and shrubs, can achieve a savings of 15 percent in annual energy consumption, 79 percent in space cooling load, and 79 percent in peak load. With an estimated total energy savings of $0.34 per square foot, the ROI for an investment in this optimum green roof is 5 percent.

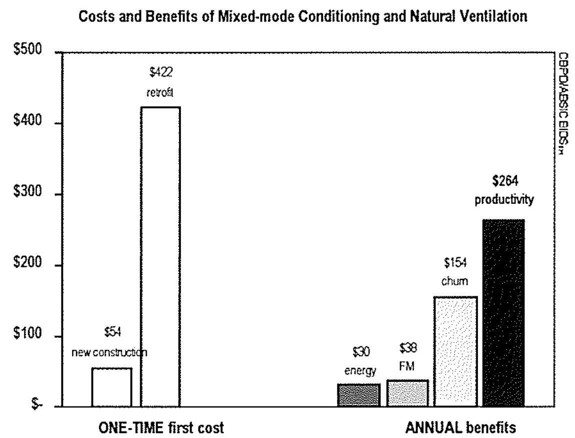


Figure 16. Cost and Benefits of Underfloor Air Systems (http://cbpd.arc.cmu.edu/ebids)

4.4 Innovative Systems Integration

There are a growing number of LEED® Silver, Gold and Platinum projects that have demonstrated measurable energy benefits as well as reduced absenteeism, quicker attraction rates, better health statistics, and more. The difficulty lies is determining which elements of the building contributed most significantly to those gains—access to the natural environemnt, high performance equipment, better materials and finish, or better coordination of the professional disciplines driven to create a more sustainable building. As we strive for innovation in buildings to ensure health and productivity, organizational and technological flexibility, and environmental sustainability, it will be critical to tease out the importance of quality in each building subsystem and system integration. To this end, one systems integration innovation, the use of underfloor air to ensure task air for each individual, has demonstrated life cycle benefits.

Task Air Pays!
Underfloor Air Systems

Implement under floor air systems to ensure 5-34 percent annual HVAC energy savings and 67-90 percent annual churn costs savings, for an ROI of at least 115 percent.

Twelve studies have shown that UFA systems can pay for themselves in less than one year due to energy, productivity, churn, and facility management benefits. The BIDS™ case studies demonstrate that UFA yields annual energy cost savings of $30 per employee ($0.14/ft2), produc-tivity gains of $254 per employee, churn cost savings of $154 per employee, and FM savings of $38 per employee ($0.19/ft2), for total savings of up to $486 per employee annually. With a one-time first cost premium of $54 per employee for new construction and $422 per employee to modify existing buildings, the average ROI for an investment in UFA is 900 percent for new buildings and 115 percent for retrofits.

The BIDS™ team has identified four case studies that indicate an average 15 percent reduction in annual HVAC energy consumption due to underfloor air systems. Five studies demonstrate an average 80 percent reduction in annual organizational churn cost due to UFA. Two studies report first cost savings of $0.43 to $2.00 per square foot for UFA systems, as compared to ceiling-based systems, while other case studies argue a first cost premium of $0.25 to $2.50/sq.ft. York[26] identifies annual FM staffing cost savings of $0.19 per square foot and Fitzner[27] shows an individual productivity improvement of 0.7 percent, both resulting from the introduction of underfloor HVAC, with the ability to customize the delivery of air in the individual workstation.

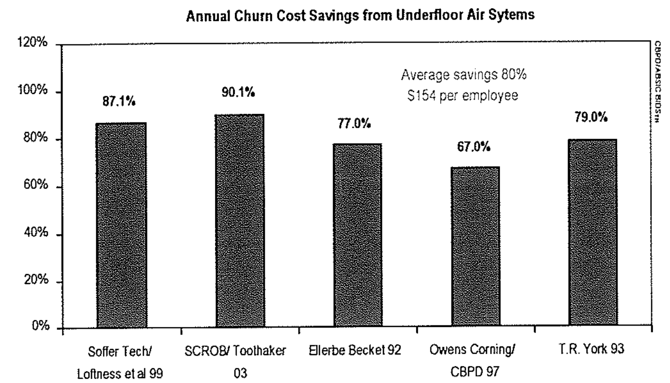


Figure 17. Churn Cost Savings Associated with Underfloor Air Systems (http://cbpd.arc.cmu.edu/ebids)

5. Conclusion

Sustainable design is a collective process whereby the built environment achieves new levels of ecological balance in new and retrofit construction, towards the long term viability and humanization of architecture. Focusing on environmental context, sustainable design merges the natural, minimum resource conditioning solutions of the past (daylight, solar heat and natural ventilation) with the innovative technologies of the present, into an integrated "intelligent" system that supports individual control with expert negotiation for resource consciousness. Sustainable design rediscovers the social, environmental and technical values of pedestrian, mixed-use communities, fully using existing infrastructures, including "main streets" and small town planning principles, and recapturing indoor-outdoor relationships. Sustainable design avoids the further thinning out of land use, and the dislocated placement of buildings and functions caused by single use zoning. Sustainable design introduces benign, non-polluting materials and assemblies with lower embodied and operating energy requirements, and higher durability and recyclability. Finally, sustainable design offers architecture of long term value through 'forgiving' and modifiable building systems, achieved through life-cycle instead of least-cost investments, and through timeless delight and craftsmanship.[28]

Notes

1. Center for Building Performance and Diagnostics (CBPD), School of Architecture, Carnegie Mellon University, 5000 Forbes Ave., Pittsburgh, PA 15213-2890. ABSIC Members that have supported the development of BIDS™: Armstrong World Industries, BP Solar, Carnegie Mellon University, Department of Energy,Department of Defense, Electricité de France, Environmental Protection Agency, Gale Foundation, General Services Administration, Northwest Energy Efficiency Aliance, PublicWorks and Government Services Canada, Siemens Energy and Automation, Inc., Steelcase Inc., Teknion Inc., Thyssen Krupp AG, Tyco Electronics, United Technologies, Carrier, National Science Foundation.
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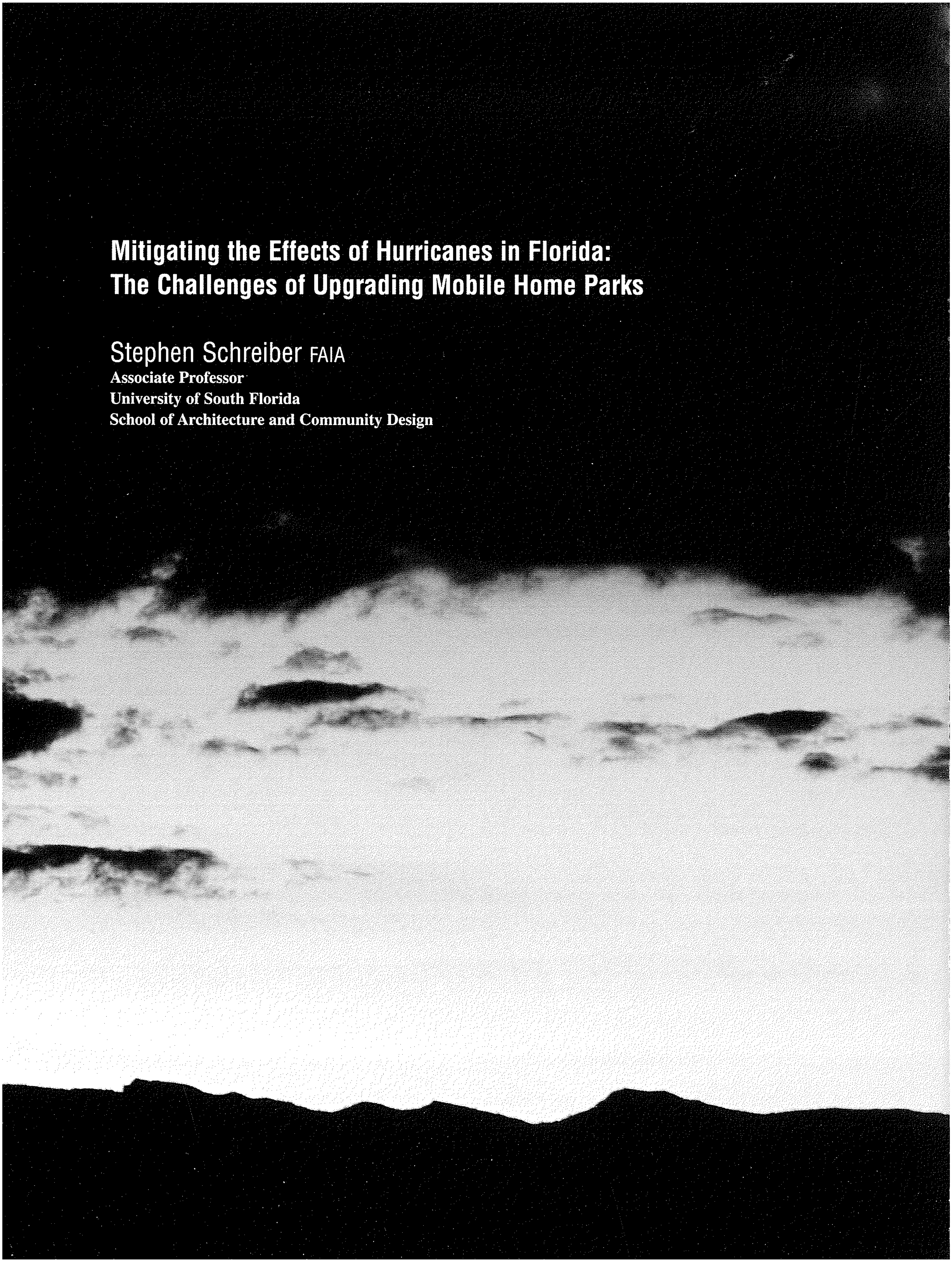
Mitigating the Effects of Hurricanes in Florida: The Challenges of Upgrading Mobile Home Parks

Stephen Schreiber FAIA
Associate Professor
University of South Florida
School of Architecture and Community Design



For the past four years, several universities have been involved in a multi-disciplinary study on how to mitigate the effects of hurricanes on residences in Florida, particularly mobile homes, which constitute a substantial portion of affordable housing in the state.

This report focuses on one track: eliminating state and local barriers to upgrading mobile homes and communities in the state (with a focus on Polk County).

This work involved interviews with mobile home owners and renters, mobile home park owners or managers, mobile home manufacturers or agents, architects, engineers, building and planning officials, as well as visits to several mobile home parks. Additionally the team conducted extensive research of existing local land-use laws, codes, plans and regulations and surveyed building officials and mobile home dealers to determine the extent of knowledge gaps with respect to regulatory environment regarding mobile homes. The importance of this research was made obvious by the 2004 hurricane season, and which four major storms created significant damage to Florida's housing stock, particularly mobile homes.

MOBILE HOMES

Florida leads the nation in the number of mobile homes. Some 2 million residents of Florida, or about 12.5 percent of the total population, live in mobile homes. In many communities, it is the only form of affordable housing. The potential for damage to this housing stock from hurricane impact is real and of the utmost importance to Florida policy-makers, public officials and a host of stakeholders including, the residents, but also mobile home manufacturers, housing developers and builders as well as design and engineering professionals. The largest numbers of mobile homes are found West Central Florida, particularly Hillsborough, Polk, and Pinellas counties.

Any issue that affects such a large segment of the population becomes a very important one not only for the residents themselves, but also for state legislators, policy-makers and others. The demographics of mobile homes residents are quite different than those of the total population of the state. These characteristics include the following: Slightly more than 36 percent of the households consisted entirely of elderly persons (65 and older); an additional 49.1 percent of the households included members 65 years of age or older; about 15.4 percent of the population are widowers living alone. These are segments of the population that could be categorized as having *special needs* especially during emergencies.[1]

There are three distinct generations of mobile homes based on their year of manufacture. Roughly these generations can be identified as: Pre-1976, 1976 to 1994, and Post-1994. The Pre-1976 units are those that were built when there were no manufacturing/design standards. Those of the 1976-1994 generation were built under HUD standards. And the Post-1994 generation incorporates stricter design and manufacturing standards including wind load standards based on American Society of Civil Engineers (ASCE) specifications.

Throughout the state of Florida, and particularly in the west central Florida region, there are significant numbers of older mobile homes in use today. Only about 14 percent of units in service have been built to the strictest wind standards while approximately 29 percent belong to the "no-standards" pre-1976 generation. This category of mobile home tends to be the most vulnerable under adverse weather conditions. A combination of factors—age, sustained use, inability to be upgraded or renovated to comply with current codes and standards, substandard modifications—contribute to unsafe and hazardous conditions. Most of these mobile home structures are of the "singlewide" configuration and were installed on either leased or purchased lots. Invariably, these structures incorporated approximately 500 to 700 square feet of floor area in a rectangular unit, and occupied regular-shaped parcels—some with typical dimensions as small as 25 feet by 40 feet.

It is unlikely that the manufactured housing industry will implement significant new changes in the foreseeable future, to further minimize the risk of property loss and damage due to hurricanes or other severe weather conditions. While modest improvements have been made in enhancing the structural integrity of mobile homes over the last two decades, current trends in this type of construction appear to be focused on increased space, the inclusion of more amenity features and enhanced curb appeal or character. Newer mobile homes have become much more appealing and marketable to that segment of the general public that will consider this form of housing as a first choice, or as an alternative to conventional site-built houses. As the inventory of newer, mostly doublewide mobile homes are purchased and installed there is an increasing supply of older ones that remain on the market and in continuous use. According to the *Tampa Tribune*:

> Mobile homes seem to be popular among winter residents and retirees and are increasingly popular with families on limited budgets. 'You can get in a brand new mobile home for as little as $28, 000,' said Scott Davis, a sales executive at Oakwood Homes. Mobile homes range in cost from a few thousand dollars to 8 more than $100,000. Rent ranges from less than $100 per week to several hundred dollars per month.[2]

Mobile homes, while affordable and easily sited, are particularly vulnerable to wind damage. They are not designed to withstand the wind velocities of a Category 3 or greater hurricane. Local emergency management agencies recommend evacuation of mobile homes for Category 1 or greater hurricanes. In coastal areas, storm surges during hurricane events can be devastating to mobile homes. Floods can cause strong pressures on foundations or piers, and floating debris can cause further damage to the exterior. Interior damage to the structure can be extensive. Some wind and flood damage can be avoided by proper installation, by raised installations using properly designed fill and/or posts, and by using tie-down. However, local building inspectors may be unfamiliar with the particular needs of manufactured houses. This may be especially true in small communities where inspectors do not specialize. Also, inspectors or inspection agencies may easily miss resold manufactured mobile homes.

Because of the dismal performance of mobile homes in Hurricane Andrew, new wind standards went into effect in the HUD Code in July 1994—manufactured homes placed in high-risk hurricane areas now must be designed to withstand approximately 100 mile per-hour winds. After the devastating 2004 hurricane season, the Florida Bureau of Mobile Home and RV Construction surveyed 152 mobile home parks in 14 counties. The survey found 4,250 mobile homes destroyed or damaged beyond repair—all were built more than 10 years ago. However, the survey showed none of the 6,371 homes built since 1994 suffered serious damage.[3]

POLK COUNTY

Background

Polk County's total population in 2000 was 484,000—about three percent of the Florida's entire population. It is the eighth most populous county in the state. Polk's total population is expected to grow to an estimated 550,000 by 2010. Approximately 63 percent of Polk County's total population resides in the unincorporated area of the county. The other 37 percent of the population live in Polk County's 17 cities. The total area of the county is approximately 2,010 square miles, which makes it the fourth largest county in Florida.

There are over 6000 licensed mobile home parks in Florida, with a total of 430,000 mobile home spaces. Polk County is home to over 500 of these mobile home parks, with nearly 46,000 mobile home spaces. The US census estimates that there are more than 50,000 mobile homes in the county, the most of any county in Florida. This number surpasses Hillsborough and Pinellas.[4]

"'There has been a lot of redevelopment and attrition in Pinellas County,' said Frank Williams, spokesman for the Florida Manufactured Housing Association in Tallahassee, explaining many mobile home parks were 50 or 60 years old and have been replaced with other types of development. Pinellas, whose total land area is only about 15 percent of Polk's, doesn't have much land available for new development, Williams said, contrasting that with Polk, which still has plenty of available land".[5] The largest of the mobile home parks in Polk has over 1000 spaces.

Local planners, building officials, code enforcement officers and residents attribute the popularity of mobile homes to the relatively low cost of living in a county between two major cities, Tampa and Orlando, and the availability of land. Part of the reason for the prevalence of densely populated parks is the fact that mobile homes are grandfathered into the zoning. Many mobile homes in Polk were built in the 1970s and predate zoning laws. The regulations have become stricter in recent years, largely because of Polk's comprehensive development plan, approved by the state in 1991.[6]

Table 1

POLK COUNTY MOBILE HOME PARKS

COMMUNITY	MOBILE HOME PARKS (registered with Dept of Health)	MOBILE HOME SPACES
Auburndale	37	2603
Avon Park	2	20
Babson Park	4	87
Bartow	15	96
Bradley	2	12
Davenport	27	4689
Dundee	7	547
Eagle Lake	1	8
Eaton Park	3	93
Eloise	1	26
Fort Meade	13	888
Frostproof	25	2705
Haines City	38	4532
Highland City	5	69
Homeland	1	7
Lake Alfred	5	487
Lake Wales	58	4056
Lakeland	173	14,903
Loughman	3	217
Mulberry	12	1445
Polk City	6	452
River Ranch	2	97
Wahneta	8	102
Winter Haven	54	6799
TOTAL	**502**	**45,810**

Constructed from Florida Department of Motor Vehicles records

Table 2

MAJOR STORM EVENTS AFFECTING POLK COUNTY: 1994-2004
Prior to 2004 hurricane season

Storm Type	Number of Events	Reported Damage to Mobile Homes
Flood	25	**1997** Six mobile homes received nearly $155,000 dollars worth of structural damage. **1998** Localized flooding of homes occurred on lakes in Polk county.
Hurricane/ Trop. Storm	13	**1999** One mobile home lost its roof from tropical storm force winds on Rock Ridge Road in Lakeland.
Tornado	34	**1997** Seventy-five homes were destroyed, another 75-100 suffered major damage while another 75-100 received minor damage. Most of the homes destroyed were mobile or pre-fabricated homes. **1997** A tornado touched down in the Oakwood Estates mobile home park along Spirit Lake Road south of County Road 540. Approximately twelve mobile homes sustained minor to moderate roof, lanai and siding damage. **1999** A tornado initially touched down in the Heatherwood Village Mobile Home Park and caused minor to moderate damage to the roofs, carports, lanais, and awnings of over 30 mobile homes. Two additional mobile home rooftops were removed by tornadic wind on Inman Drive while a shed and carport were destroyed at the intersection of Dorothy Street and Central Avenue. **2002** A small tornado, which began as a waterspout on Lake Smart, briefly touched down at a mobile home park just north of Lake Smart in eastern Polk County.Minor damage was reported to 14 structures, with three of them having roofs partially torn off. **2004** Polk County Emergency Management completed a storm survey and found shingles stripped off a brick home and four mobile homes with minor damage, including damage to skirting, awnings, and attached shed. An eyewitness watch a thin tornado move through the area. The wind speed of the tornado was estimated at 70 mph.
Thunderstorm High Winds	128	**1993** Strong winds knocked a mobile home off its foundation. **1993** Two houses and eight mobile homes suffered severe damage in Winter haven. **1995** A thunderstorm downburst of 45 mph damaged two carport roofs at a mobile home park. **1995** Thunderstorm winds damaged ten manufactured homes and eight six-unit apartment buildings near Fedhaven. Estimated damage of $250 thousand. **1996** Twelve mobile homes, two sheds and a screen enclosure were also damaged by thunderstorm winds. Most of the damage occurred on North Lake Lulu Drive and Rolling Oaks Drive in the Oakwood Estates subdivision. The wind blown debris was scattered over a four-block area. **1997** Thunderstorm winds overturned and demolished five mobile homes on wheels at the Homes of Merit mobile home plant located at the Bartow Airport. Three additional mobile homes at the plant incurred minor structural damage. **1997** Four mobile homes suffered moderate roof damage, crumpled carports and screened porches at the Cypress Greens and Lake Alfred Mobile Home Parks **1997** Thunderstorm winds ripped off the roof of a mobile home on Sonora Road near State Road 557-A. **1997** Thunderstorm winds overturned a mobile home on Alderman Road, damaged mobile homes at the Hampton Mobile Home Park and downed several trees along U.S. Highway 92. **1997** Thunderstorm winds overturned a few mobile homes and damaged the roofs of twelve others in Bartow. Four of the mobile homes were destroyed. **1997** Two mobile homes sustained major roof damage from thunderstorm winds at the Royal Oak mobile home park. Thunderstorm winds up to 50 mph caused minor porch roof and skirting damage to 16 to 20 mobile homes in the Pine Lakes Estates and Imperial Lakes subdivision in Lakeland. **1997** Thunderstorm winds caused minor to moderate wind damage to 30 mobile homes in two mobile home parks in the vicinity of Harden Blvd. and Beacon Road. Three of the mobile homes incurred minor roof damage while the majority of the damage was limited to carports and awnings. **1999** Thunderstorm winds, estimated at 50 mph by the public, caused minor damage to carports and screen porches of ten manufactured homes in the Four Lakes Golf Club Manufactured Home Park of Winter Haven. **2001** The Polk county sheriffs department reported that thunderstorm winds caused moderate to minor damage to twelve mobile homes and caused minor hangar damage at the Lake Wales Municipal Airport. **2002** Estimated 50 mph (43 knot) winds at the Dawn Heights mobile home park produced minor damage to awnings, porches, and windows. **2003** Thunderstorm winds downed trees and blew the roof off a mobile home. **2003** Thunderstorm winds took the roof off of a mobile home, destroyed a car port, and pushed trees onto at least two vehicles.
TOTALS	**200 events**	**Damage to at least 460 mobile homes**

Constructed from NOAA records available at http://www.ncdc.noaa.gov

The market is greater in unincorporated sections of the county because mobile homes are not as welcome in cities. There are no separate districts for mobile homes in unincorporated Polk County. Polk County's "mobile home friendly," said Christina Hummel, a senior county planner. "If your neighbors have a mobile home, you can have one, too. It's a majority rules situation."[7]

The Strategic Regional Policy Plan, of the Central Florida Regional Planning Council provides this assessment of the mobile homes in the region:

> The only segment of the housing market that has answered the call for affordable units is the mobile/manufactured housing industry. Mobile homes, both in planned communities and sold as individual units, have the largest market share in the affordable category, because they are generally less expensive than conventional housing and often require as little down payment as a car, but they present unique problems in the Region. Ineffective local policies governing the placement of mobile homes, which are reinforced by the State's misplaced assumption that permissive regulations and minimum infrastructure makes them affordable housing, only adds to the depreciation of the housing stock in Central Florida counties. In addition, the spread of mobile homes dramatically increases the risk of storm damage to a growing portion of the population.[8]

Storms

While Polk County does not have any coastal areas, it suffers from frequent severe storms year round. According to the National Oceanic & Atmospheric Administration (NOAA), 200 severe storm events (floods, hurricanes/tropical storms, tornadoes, and thunderstorms) damaged at least 460 mobile homes in Polk County between 1994 and 2004 (prior to hurricane season). This indicates that about 1 percent of the mobile homes in the county were damaged—by wind and/or water events—in less than a decade, in a period that no major hurricanes hit the area directly.

In 2004, three major hurricanes crossed over Polk County and damaged or destroyed about 15 percent of the mobile homes in the county. Nearly 500 mobile homes were destroyed and about 5,806 mobile homes were damaged in Charley, according to Polk County officials. Nearly 166 mobile homes were destroyed during Frances, and another 435 sustained major damage. Jeanne left 660 mobile homes with major damage.[ix]

Zoning and Building Codes.

The Polk county study area for this research is comprised of 18 governmental jurisdictions: the County of Polk and its 17 incorporated cities (Lakeland, Winter Haven, Auburndale, Bartow, Davenport, Dundee, Eagle Lake, Fort Meade, Frostproof, Haines City, Highland Park, Hillcrest Heights, Lake Alfred, Lake Hamilton, Lake Wales, Mulberry, and Polk City).

Zoning information was obtained by an electronic search was conducted on www.municode.com using "mobile homes" as the primary key words for several representative communities. The Polk County Land Development Code is available on the county's web site.

At least eight jurisdictions within the study area have identifiable zoning/land use districts that specifically recognize new or existing mobile home residential developments. These eight include: Davenport, Dundee, Eagle Lake, Lake Wales, Lakeland, Polk City, Winter Haven, and Polk County. "We permit them in mobile home parks and mobile home subdivisions, but not on individual lots," said Lakeland planner Bruce Kistler. (Palmer) Winter Haven also restricts mobile homes to mobile home parks.

Numerous zoning codes for Polk County (analyzed as part of this phase) and Hillsborough and Pinellas Counties (analyzed in an earlier phase of this project) include requirements that should be building codes—especially for tie downs, additions, foundations. Zoning officials, in many cases, do not have the expertise or training to enforce these requirements.

The duplication of information and requirements in the zoning codes and building codes is confusing to consumers, government officials, and building professionals. Often times, building code issues were added to zoning codes, because it was a simpler process to change the latter in certain municipalities. However, the result is a lack of clarity as to which code—zoning or building—addresses important health safety and welfare issues, such as tie downs, additions, and maintenance. The team was concerned about the significant number of site built attachments to mobile homes in the parks it visited. Most zoning codes have authority over the locations of residential structures, but the laws are unclear, or apparently unenforced, for mobile homes within parks. The site built additions are a significant cause of windborne debris in hurricanes.

Several jurisdictions contain mobile home anchorage requirements in their zoning regulations. While these documents' intention may be to draw emphasis to this critical need, the inclusion of these requirements in the zoning codes is problematic. This is an on-site construction matter that is more properly addressed in the communities' building codes. (In the field, the team observed many older mobile home units with rusting, missing, improperly installed tie-down straps).

No Polk County zoning codes specifically address mobile home maintenance.

In fact, poorly maintained units plague many areas of the county. For example, as reported in the *Tampa Tribune*:

> For others, mobile home living is a necessity. Katrina Kirkland pays $250 a month rent to live in a rundown trailer on a dirt road in Kathleen, a community north of Lakeland. She shares the home with her daughter, Beth Stephenson, and three grandchildren. The home isn't in the best shape, Stephenson said. "The windows leak and don't open. The walls are falling apart. If you look behind our couch, you can see daylight"[10]

According to *Strategic Regional Policy Plan*, Central Florida Regional Planning Council:

> Mobile home communities, which are generally safer than individually sited units due to tougher development standards, are not being developed to meet the demand for affordable units among the two groups who need them the most: the farm workers and the low income wage earners.[11]

Land Use

A threat to Polk County mobile home parks is incompatible land use. Polk County itself allows mobile home parks in several different land use zones. Many parks are not located in compatible zones, and are susceptible to development and commercial and other uses. It is often the parks in incompatible land uses are poorly maintained, and vulnerable in storms.

Of the 436 parks the team could locate, 273 are located in unincorporated Polk. About three-quarters are in compatible districts. (A detailed analysis was not conducted to determine whether or not the parks meet current zoning standards.) Those that are not are susceptible to development and commercial and other uses.

Some Polk County zoning ordinances address flood and wind damage control for future development but appear to have a limited impact on the existing conditions. Since these regulations usually apply only to new parks, or to new mobile homes within parks, most existing mobile home parks have not been upgraded. This is particularly problematic, because the 2000 flood maps for Polk County show that 40 percent of the county is in a flood zone. In Polk County, 109 out of 436 mobile home parks (that the team could locate) are positioned within 1000 feet of a lake or other waterway, the most likely flood hazard in this non-coastal area. Almost all are within a mile of a lake.

Platting issues

Given the number of older mobile home units still in use today, it is reasonable to explore alternatives that will minimize the potential of human injury and loss of life, as well as major property damage and destruction resulting from their continued use. One approach is to adopt policies and regulatory measures for retiring or phasing out older mobile home units, and replacing them with small "site-built" houses. This approach suggests that older mobile home parks with units in excess of thirty years old, phase in a "cottage development" pattern (detached dwelling units), or one that incorporates a modest form of "party-wall" residential construction. This approach would over time, make use of the original mobile home lot platting patterns, by replacing older mobile homes with another form of affordable housing that will withstand the elements far greater than the older structures they replaced.

Most mobile home parks in Florida were platted for travel trailers; or older, small singlewide mobile homes. Modern larger mobile homes, with safer design features, do not fit on the older plats. Therefore park owners are unable to accommodate new mobile homes and maintain required setbacks. The team investigated several case studies of parks where these barriers exist, and propose solutions for replatting and/or modification of setbacks.

In general, mobile home parks tend to follow the patterns of larger residential subdivisions developed at the same time. That is, many were developed on a strict gridded format at a time when other residential communities were so-planned, and more recent parks have moved to an arterial model at the same time that residential suburbs have done so. Many mobile home parks also embody many of the principles of good urbanism: narrower, pedestrian-friendly roadways with low speed limits; the close proximity dwellings to the roadway; and the enhanced abilities of home occupants to observe and interact with passersby. Many parks have an abundance of front screened porches and lanais (due in part to the frontal orientation of the units and their smaller size which creates an incentive for residents to create additional spaces by adding outdoor living spaces) and gathering places (such as local community mailboxes, recreation centers, swimming pools, and management offices).

Park layout does not have a direct physical impact on storm survivability, but layouts can affect the sense of community. Strong community pride is directly related to safer neighborhoods with greater potential for successfully surviving major traumas such as hurricane and other storm events. Additionally, alternate park layouts may allow for increasing densities that would promote the economic viability of the manufactured home parks as businesses and thereby continue to provide a stable housing alternative.

The team analyzed "small unit" housing alternatives: structures that resemble mobile homes in size, configuration, and affordability. These newer, permanent homes are inherently safer due to the incorporation of stricter building codes. As well, being larger, they may reduce the need for outbuildings and attached structures.

Most manufactured home park share many similar characteristics, such as an emphasis on the narrow end of the lot facing the street, setbacks on all four sides of the unit that result in the unit being centrally located on its lot, and a lack of usable green space in the area immediately surrounding the unit.

Park reconfigurations involve the replacement of the current manufactured home stock with new, permanent structures. This would represent a substantial investment on the part of the homeowner and, if the land were still to be rented, may require a change in lease terms. It is possible to consider changing the legal structure such that the dwelling occupants own the lots. It is unlikely that the resulting homes would be as low-cost as the existing housing units. However, the changes would retain the higher density of the land use while still retaining the community characteristics of the existing parks.

The small parcel layout is common in older mobile home parks in the west central Florida area, and allowed for a convenient and economical use of land for platting purposes. While the resulting close proximity of individual mobile home units may suggest some degree of perceived shelter, the fact remains that the structural integrity of most, if not all of these homes in questionable under abnormal or extreme weather conditions.

The team found that it is not feasible, nor practical to try to renovate or upgrade older mobile homes. The costs associated with any such investment would not be effective in realizing any significant benefits. Any serious attempt at renovating these older structures would ultimately prove to be exorbitant in cost and face the following barriers (among others); an inability to support appreciating values, difficulty in complying with current codes, continuing poor performance in providing shelter that can reasonably withstand severe natural weather phenomena.

Several municipalities, in west central Florida have a variety of zoning and other code restrictions that do not allow mobile homes and mobile home parks. Most of these ordinances have "grandfathered in" many older mobile home facilities. Cities and counties are faced the challenge of what to do with these older mobile home structures, from a public safety point of view. Some are considering creating "small lot" or similar ordinances that permit small, site-built dwellings on atypically small lots. These types of ordinances would allow for the phased or sustained replacement of older mobile homes with more stable structures that will help minimize property loss and damage in severe weather conditions and also enhance the physical character of these communities. In many instances, the use of similar types of "replacement" ordinances can serve as progressive and proactive measures for minimizing mobile home property loss, as well as general public safety in these areas.

The team studied two precedents that can be looked at to provide insights on the use of small-lot platting for single-family housing, both in Pinellas County; Yachthaven, a mobile home park being converted to permanent housing in Largo; and the re-use of former mobile home lots in Indian Shores.

Yachthaven Estates

Yachthaven Estates community area was developed as mobile home subdivision in unincorporated Pinellas County in the 1950s and through resident petition annexed into Largo in 1966 by referendum. There are currently a total of 73 lots that were created through metes-and-bounds lot splits and the dedication of additional right-of-way to access the lots. The area was originally platted as a two-phase, 34-lot single-family subdivision. Since its inception, the property has been developed with mobile homes. Residents discovered that they were in difficult position of being unable to replace their mobile homes (because they were in a flood zone) or construct site built houses (because lot sizes were too small). Thus the neighborhood was unable to upgrade the deteriorating mobile home stock.

> [A home owner] discovered, at the worst possible time, that she and the other residents in the Yachthaven Estates mobile home community are stuck in a web of city, state and federal regulations, unable to replace their homes even if they are damaged or destroyed by hazards. They can't replace them with mobile homes because their community is in a flood zone and coastal high hazard area, and because it is not legally described as a mobile home park. So when their old, 1950s-era, mobile homes deteriorate to the point of needing replacement the only option is to build houses on site. But other laws require site-built houses have to be on minimum lots of 5,808 square feet. Almost all the lots in Yachthaven are smaller than that. Some are half that size. Factor in required city setbacks of up to 20 feet, and that doesn't leave room for much of a house, even if a house were allowed.[12]

In June 2003, the City Commission of Largo approved a neighborhood plan that made all the lots legal, creating an exception to city codes. Mobile homes are still not being allowed, but modular, wood, masonry or any other construction that meets Florida Building Codes is approved. The plan also would reduce the required front setback from 20 feet to 10 feet. The smaller lots (e.g., 40 ft. x 60 ft. and 45 ft. x 90 ft.) are allowed to redevelop in one of three ways:

- Individually, as single-family residences following the same standards applied to the other lots;
- "Together" as two single-family attached (zero lot line) residences with a single-family appearance. Each unit must be maintained on as a separately deeded parcel capable of being independently owned and sold;
- Be combined into one lot (without requiring replat), allowing them to be returned to the same size as the other surrounding lots.[13]

Indian Shores

The Town of Indian Shores has initiated an effort to redevelop several acres of land that was originally platted for mobile homes back in the late 1940's. This "paper" subdivision, so named as a result of its original speculative and "impermanent" nature, is currently in the city's Town Square Planning Area. It was originally laid out as five slender blocks running parallel the main north-south thoroughfare. Characteristic of a typical surveyor's plat for a mobile home park, this area had just fewer than 200 lots each with dimensions of 25 feet by 40 feet. Although all of the original mobile homes are gone, several of the lots were improved over the years with various types of site-built structures. Today, the town is considering redeveloping the remaining vacant lots in this subdivision with various types of "live/work" townhouses. This type of party wall construction is very appropriate for this type of narrow-lot platting. Several years ago, the Town enacted restrictions on placing mobile homes on these lots because of their proximity to the Gulf coast and the likelihood of major property damage following a hurricane or storm. This has created an opportunity for the Town to re-claim all of the land from this former mobile home park and adapt it to a small-lot subdivision with a more stable form of site-built houses.

KEY FINDINGS

While this project focused on obstacles to upgrading mobile home parks, identified an even larger problem in west central Florida—the scarcity of low-cost housing alternatives, and programs to assist the poor in ameliorating their housing. Typically, the oldest and most decrepit mobile homes are occupied by the least advantaged members of society. The occupants cannot afford to pay for the newer, better and safer units. To the extent that the mobile home market operates like the automotive market it accommodates all comers. The fundamental notion of upgrading mobile home parks by re-platting and installing newer and larger manufactured homes contains a fallacy: the poorest segment of the existing mobile home parks will be squeezed out, and will be left homeless. Also, manufactured units that would fit on many existing lots are available, but typically are not promoted by the industry, according to some sources, which prefers to sell double-wide units.

In the process of conducting the research for this report, the researchers discovered numerous gaps in information that impeded the team's progress. These same gaps can be barriers to upgrading mobile home parks in west central Florida.

The estimate of the number of mobile homes in Polk County varies widely. In Spring 2002, for example, the Tampa Tribune estimated that there are 84,000 mobile homes in the county, while the Lakeland Ledger estimated the number to be 50,000. The Ledger's on-line guide to the county gives different number: 61,000 mobile homes. The research team counted 46,000 mobile home spaces in mobile home parks from data provided by the Department of Health. The wide range of estimates indicates that there are probably a large number of mobile homes that are not accounted for (and not inspected).

Addresses for mobile home parks in Polk County are listed in a wide range of formats on Department of Health documents. The same road might be indicated by its local informal name; by the county, state, or federal route number; or in some other manner. These discrepancies made it very difficult for the team to geocode many of the parks for the GIS based maps. Site plans of mobile home parks on file are presented in a wide range of formats. Many are sketched, not to scale, and/or not accurate. These poorly drawn site plans make it difficult for inspectors to identify possible zoning or building code violations. Also, representatives of government agencies are not always aware of how to find these site plans. For example, representatives of the planning and building departments for several jurisdictions, had no copies of these site plans, and were not aware what agency did have them.

Only 11 of the 18 jurisdictions in Polk County have zoning information available through Municode or other searchable means. However, even this information is not easily found through most of the communities' web sites. Polk County does have a link to frequently asked questions about developing mobile homes in the unincorporated county.

While 40 percent of Polk County is in flood zones, this information is not available on line. By comparison, several Florida counties include storm surge and flood maps on their web sites, as a means of educating the public. Similarly, GIS based information for land use, demographics, and other conditions in Polk County are not readily accessible.

> The review of the many codes and ordinances indicates that multiple regulatory approaches are used to render such developments economically unfeasible. These zoning regulations attempt to mitigate the scope of damage to mobile homes as the result of hurricanes by attempting to limit further mobile home developments. It cannot be contended that local land use regulations or political factors have forced mobile home parks into high hazard areas, as most mobile homes in Polk County were constructed before hazardous areas were clearly articulated and mapped.

Zoning ordinances address flood damage control for future development but appear to have a limited impact on the existing conditions. Local zoning codes do attempt to mitigate flood damage, but they do not appear to make any positive attempts to provide similar protection against damage caused by high winds. Many jurisdictions contain mobile home anchorage requirements in their zoning regulations. While these documents' intention may be to draw emphasis to this critical need, the inclusion of these requirements in the zoning codes is problematic.

Many existing parks maintained an obvious sense of community pride. These parks foster positive interaction between management, residents in the park, and in the neighboring area. However numerous parks appear to suffer from confusing site design, poorly managed operations, and little interaction between residents. The residents of these parks seem less concerned and informed about storm related issues. Good community design appears to facilitate communication about hurricane matters.

NOTES

1. See complete report on the International Hurricane Research Center web site: http://www.ihrc.fiu.edu/lwer/hlmp_index.htm
2. Deborah Alberto, "Polk Mobile-izing," *Tampa Tribune* (May 6, 2002): 1.
3. Robin Benedick, "A Test of Strength," *South Florida Sun Sentinel* (November 26, 2004): 1
4. Alberto, "Polk Mobile-izing," B-1
5. Benedick, 1.
6. Julia Ferrante, "Mobile Homes Dot Polk," *The Ledger: Guide to Polk 2002,* undated.
7. Alberto, B-1.
8. Central Florida Regional Planning Council, *Strategic Regional Policy Plan,* undated.
9. John Chambliss, "Charley Damaged More Than Frances," *Ledger* (September 24, 2004)
10. Alberto, B-1
11. *Strategic Regional Policy Plan.*
12. Kelley Benham, "Neighborhood stuck between law, reality," *St. Petersburg Times* (March 16, 2003): B-2.
13. City of Largo, *Yachthaven Estates Neighborhood Plan* (April 12, 2003).

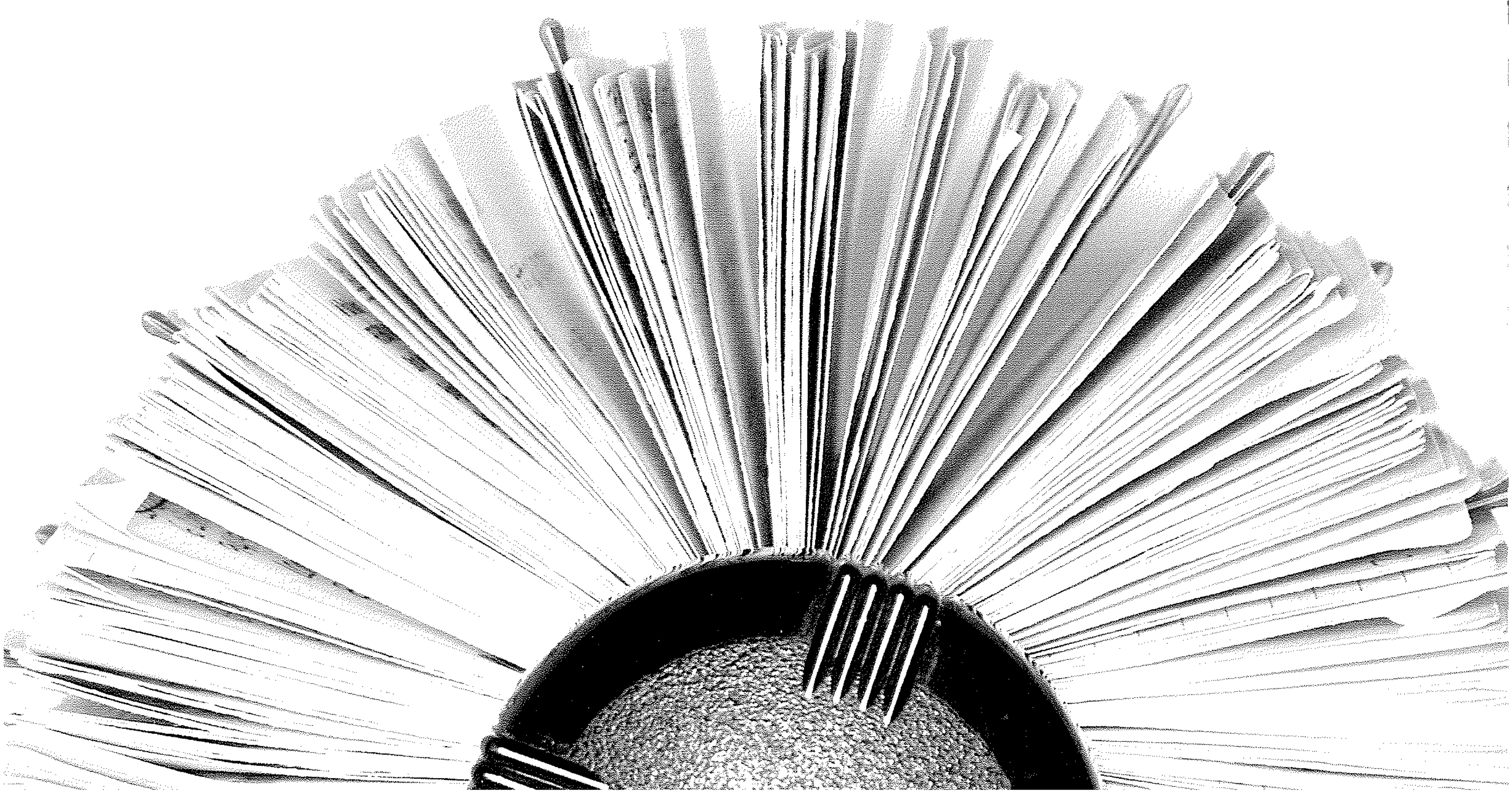
ACKNOWLEDGEMENTS

This research was supported by funding from the Florida Department of Community Affairs, through the International Hurricane Research Center (IHRC) at Florida International University (FIU). University of South Florida (USF) architecture faculty, who have been involved in this multi-year project, in addition to the author, have included Dan Powers, George Epolito, Theodore Trent Green, and Alexander Ratensky. USF graduate student research assistants have included Deepu Bhattacharjee, Michael Dailey, Swapnali Salunkhe, Kevin Nickorick, Laura Lake, and Johanna Ossmann. The author also acknowledges and thanks Richard Alvarez (IHRC), Tim Reinhold (Institute for Home and Building Safety), and Jason Chandler, AIA (FIU).

Sharing Tacit Design Knowledge in a Distributed Design Environment

Jeong-Han Woo
Mark Clayton
Robert Johnson
Benito Flores
Chris Ellis

Texas A&M



The AEC industry has realized the value of capturing, storing and reusing architects' design knowledge that is mostly tacit. Tacit design knowledge is highly personal and implicit knowledge. As such, it encompasses design capacity, expertise, intuitive understanding, and professional insight formed as a result of design experience. Throughout the life cycle of a design project, architects rely heavily on their tacit design knowledge to support design decisions (Schon 1983). Therefore, to achieve greatness, architectural firms try to hire good architects with in-depth design knowledge and expertise. Ron Skaggs, Chairman and Past CEO of HKS, has stated that the employee is HKS' greatest resource (Skaggs 2002).

Current architectural design process has been described as a multi-participatory distributed design environment (Huang 1999) to which architects bring their own expertise from remote locations. Architects' tacit knowledge holds tremendous value if made reusable for the right project at the right time. Therefore, the firms' main concern is how to hire accomplished professionals who will apply their architectural expertise to projects at the right time.

In a large architectural firm, work is sometimes duplicated because people are unaware of each other's work in remote locations. Consider a senior architect in a Dallas, TX, office who previously conducted several office building projects and a novice architect in Tempe, FL, office who is developing an office building design for the same client. These people could share extensive information if they were aware of one another's work and connected at the right time.

Due to its implicit nature, tacit design knowledge is typically shared only among colleagues who work in the same office through face-to-face interactions. One way to share tacit design knowledge is to encourage architects to engage in more informal conversations as a form of "Communities of Practices" (Brown and Duguid 1991). The essence of informal conversations is a cooperative attitude that fosters collaborative work on projects. They can share and synchronize information and design knowledge among themselves.

Furthermore, with emerging CMC (Computer-Mediated Communication) technologies, architectural design process faces new opportunities for capturing and reusing tacit design knowledge. The information systems of an architectural firm could support these perspectives, not merely exchange drawings or documents. Intranet or Virtual Private Network (VPN) could incorporate CMC technologies to allow individuals to talk to each other informally. However, there is no accepted and guaranteed CMC strategy for managing tacit design knowledge in the AEC industry.

This paper elaborates the concepts of design knowledge sharing in a distributed design environment by documenting close empirical observations in a graduate level architectural design studio. This paper further investigates the impact of tacit design knowledge that has been captured and shared using online, interactive chat-based software that was developed by the researchers.

The software was tested in a graduate level architectural design studio in which design students sought advice from experts in remote locations. The design studio required students to address highly technical topics outside their previous education, such as sustainable construction, cost and constructability analysis, and landscape design.

Content, time, participant characteristics, and other data from chat sessions were recorded and documented. The data were analyzed using qualitative and quantitative methods, including content analysis, protocol analysis, logs, frequency counts of dialogues, simple statistics, and questionnaires.

Literature Review

Reviewing the extant literature on theories of tacit knowledge, virtual design studio, and CMC technologies elaborates theoretical foundations and provides some preliminary answers to these unexplored questions: How can CMC assist in capturing and sharing experts' tacit knowledge? What are the problems associated with the integration of CMC into a distributed design environment?

Theory of tacit knowledge sharing

Few researchers in the field of architecture have rigorously studied the importance of tacit knowledge sharing in architectural design environments. However, Schon (1983) convincingly demonstrates that experts' tacit knowledge is a very important resource in the architectural profession. He explores the traditions of the architectural studio to investigate how architectural students learn from instructors in a design studio, insisting that design knowledge can be shared by reflective conversations within a design situation. Suwa et al. (1998) also stress the importance of tacit knowledge in the design profession, especially in an educational sense. Likewise, Cross and Cross (1995) conclude that the knowledge sharing process of design significantly influences the quality of design.

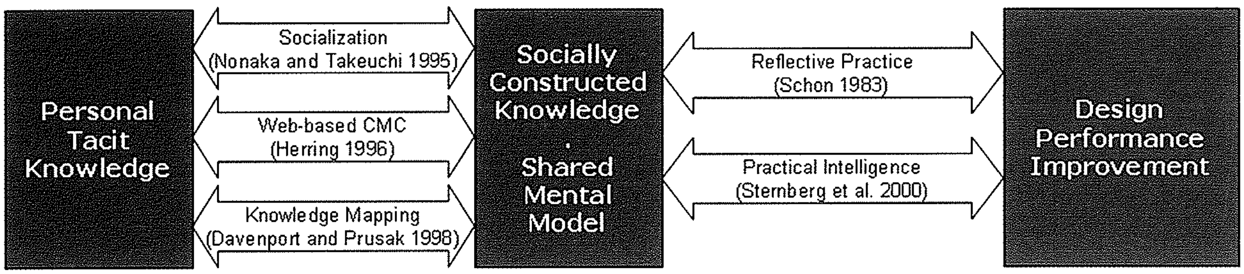


Figure 1. Theoretical Background

CMC technologies in a distributed design studio

In the field of CMC research, a few articles (Isaacs at el. 2002; Ribak at el. 2002) report several key findings where online chat or instant messaging systems successfully support tacit knowledge sharing in a typical business environment. They also argue that CMC could improve access to tacit knowledge and might offer an organization a competitive advantage by improving its efficiency and expertise.

A major limitation of current architectural research is that little research examines the potential of CMC to support architectural design processes in a distributed design environment. Few design studies have been conducted concerning the effects of CMC on the architectural profession. Huang (1999) studied the implications of collaborative media on design process by employing organizational economics theories. Kvan and Candy (2000) conducted experiments to investigate the role of CMC technologies on collaborative design communication over computer networks. In their study, chat-based software played a significant role in producing effective design communications. However, their research does not explore the impact on the design artifact of reusing tacit design knowledge; rather, they focus on facilitating design communication.

A main concern among observers and researchers is how CMC technologies might affect design performance. Maher et al. (2000) conducted an experiment in a virtual design studio to compare face-to-face communication with CMC communication to test how CMC technology changes the process of design communication. The findings indicate no significant difference between face-to-face and CMC communication. The results of these studies partially support the premise that design communication could be increased by using CMC technologies for virtual knowledge sharing.

Based on the literature review, a theoretical model (see Figure 1) was initially developed by combining and extending of the work of Davenport and Prusak (1998), Schon (1983), Sternberg et al. (2000), Nonaka and Takeuch (1995), and Herring (1996). The theoretical model shows that knowledge sharing starts with the identification of an appropriate knowledge holder, which involves the concepts of knowledge mapping (Davenport and Prusak 1998). Nonaka and Takeuchi (1995) insist that a process of sharing tacit knowledge lies in the socialization which create socially constructed knowledge and shared mental model. Herring (1996) focused research on the use of Web-based CMC for knowledge sharing. By accessing socially constructed knowledge, job performance could be improved as a form of practical intelligence (Stenberg et al. 2000). This theoretical model was later revised by interpreting the research results at the conclusion of this study.

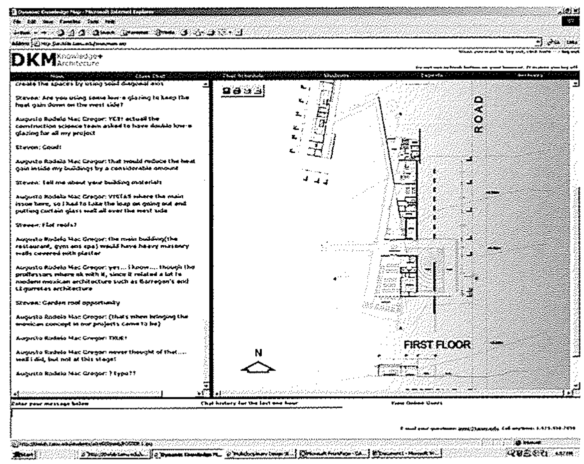


Figure 2. Screen Shot of a Chat Session

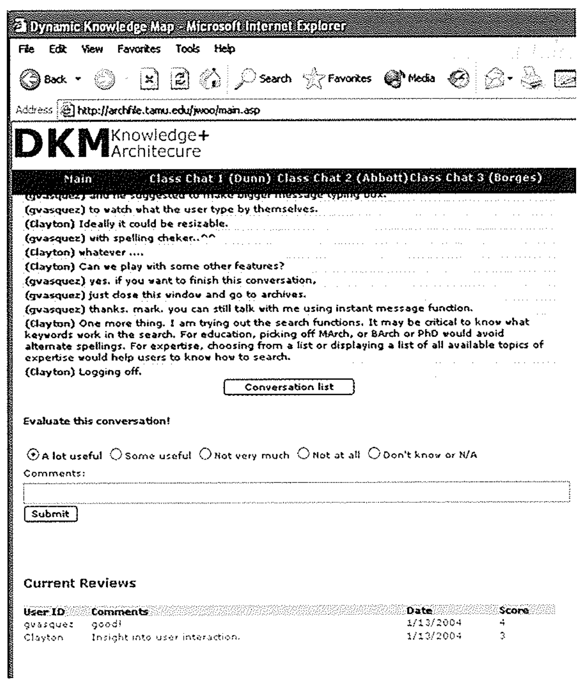


Figure 3. Screen Shot of the chat Archives and the Grading Function

Research Overview

The intuition behind the research is that rich telecommunication systems provided by the Internet can be a successful way to convey tacit knowledge about architectural design. A review of literature and theory supports this intuition and helps define a theoretically attractive software environment of Internet-based chat that is enhanced by graphic and visualization tools, supported by a database system, and delivered through Web technology.

To learn about how such a tool affects the exchange of tacit knowledge, an experiment was conducted in the setting of a graduate design studio in a College of Architecture. The experiment required the invention of a software tool and its implementation on the college network. Students used the software to seek tacit knowledge to apply to their design projects by communicating across the Internet with design critics. The documents recorded by the software were used in conjunction with demographic data and interviews to draw conclusions about the use of the software to support tacit knowledge exchange during a design project.

Software

The software used in this study was designed to demonstrate new methods of sharing tacit design knowledge that include locating, selecting, and communicating across the internet. One major function is to support synchronous chat with design experts as they offer design knowledge while simultaneously sharing architectural images (see Figure 2). Software users can also search for experts using categories of expertise, key words, and indexed transcripts of chat sessions. The system then facilitates communication with those experts though chat sessions.

All dialogues are saved in a database as records of tacit knowledge sharing, and make accessible for a knowledge seeker to retrieve them for subsequent use of tacit knowledge conveyed in the dialogue. In addition, a grading function enables the system to develop a sense of the usefulness or reliability of experts on various design topics (See Figure 3).

Methods

The instrumental case study approach (Stake 1995) was used in this research. The aim is to provide a description and understanding of what happened during design sessions by conducting formal observations and an in-depth analysis of data. In this research, two design studios were selected as cases to gain in-depth insight into design knowledge sharing processes. This paper presents the results of the first design studio only. The results from the second case will be presented in future reports.

The impact of tacit knowledge sharing cannot be judged by a single criterion due to the complexity of knowledge transfer processes. Stake (1995) also emphasizes the importance of multiple data sources in an instrumental case study to provide multiple perspectives and increase reliability. Therefore, data were collected and analyzed using both qualitative and quantitative methods to enhance the validity of findingsthrough content analysis, log files, timestamps, simple statistics, and questionnaires. Quantitative data such as questionnaire results, log files and counts of frequencies of software use will supplement qualitative observational data to triangulate evidence, producing more valid conclusions.

Setting

The case study was conducted in a graduate-level multidisciplinary design studio at Texas A&M University, College Station, TX, during spring 2004 semester. The design studio undertook a design project for the long- term planning and design of facilities at the Peckerwood Garden in Hempstead, Texas. The Garden is an outstanding repository of rare and unusual plants and unique folk art from Mexico and the United States.

The design studio was organized by three faculty members as a collaborative project involving each of the three departments in the College of Architecture: Department of Architecture, Department of Landscape Architecture and Urban Planning, and Department of Construction Science. Graduate students from the Master of Architecture, the Master of Landscape Architecture, and the Master of Science in Construction Management were enrolled in the course. The three instructors met with the students during the regular studio time. The design studio met twice a week for 6 hours per session throughout a 15 week semester.

As an additional communication medium, the software was introduced and employed by the students as a complement to traditional face-to-face design critiques. Numerous online design critiques using the software were conducted. In many instances, the online sessions involved practitioners or consulting professors who participated from remote locations. The computers used for the chat sessions are located in a college computer lab and typical, commodity personal computers. The lab is very convenient to use and has carefully been secured so that students cannot change computer configurations or network settings.

Participants

The participants included students, who may be thought of as "knowledge seekers", and design critics, who may be thought of as "knowledge providers." Twelve graduate students participated in the training and pre-test questionnaire. Of these initial participants, seven students participated in real-time chat sessions and completed the post-test questionnaire. The participation in the research was voluntarily and had no bearing on their course grade.

Category	Average	Max.	Min.
Age (Years)	25	29	22
Work Experience (Months)	16	30	0
Design Studio Experience (Frequencies)	11	20	6

Table 1. Characteristics of the Students

Seven design critics were selected and invited to contribute to chat sessions as knowledge holders. The design critics are leading faculty members, practicing architects, and industry experts. They participated using the Internet from remote locations, including other parts of the campus, Dallas, Houston, or Washington, DC. The design critics were recruited to enable students to gain tacit design knowledge at a higher level in a practical situation.

The preparation and training was planned carefully in order to have the greatest impact. Prior to the training session, a questionnaire was distributed to gain an understanding of the background of the participants and identify their demographic profiles.

The participants' average age was 21 years. They had one or two years of work experience and had previous experience on the same type of project. The pre-test questionnaire results indicate the demographic and educational background of the students as well as their work experiences (see Table 1).

Data

Two qualitative data sets were used for the content analysis: online chat transcripts and students' design artifacts. Content analysis of the chat transcripts and the design artifacts provides qualitative evidence for the effectiveness of the software for sharing tacit design knowledge. The online chat transcripts comprise messages between design reviewers and groups of students. The participants shared past design experience, professional recommendations and intuitive expectations. The chat sessions also included the identification, clarification and explanation of real problems. The records of dialogues show significant influences upon the students' approach to conceptual design.

Analysis of the chat transcripts consisted of an iterative search for design knowledge that was meaningful for the design projects. The students' design artifacts were comprised of drawings and posters produced in the design studio. Students' design artifacts were examined to discover any improvement resulting from the online chat conversations.

Quantitative data mainly supplemented qualitative observational data to triangulate evidence, which produces more valid conclusions by enhancing the internal validity of observational data. Two questionnaires were distributed to the participating students to collect quantitative data. The online student questionnaires consisted of 4-point Likert type and semantic differential scale check boxes. The submission of all questionnaires was completely voluntary and was not required by the instructors or the researchers.

Numerical data about actual usage of the software was collected by log files. These log files effectively recorded every action that every user performed within the software, including logging in and out; creating, joining, and leaving dialogs; and reading chat archives.

Procedure

After conducting a training session for the students, the first questionnaire was made available on the first day of the experiment and collected descriptive data about students' attitude toward gathering design knowledge, previous design experience, tacit knowledge utilization, computer skills and the use of CMC. The questionnaire data were used to determine whether the student characteristics were initially equivalent on the questions, even though the groups were not formed by random assignment.

The design artifacts were collected twice: before and after the series of chat sessions. The second survey was made available on the last day of the design studio. The second, post-test questionnaire was primarily designed to obtain feedback about software usability, ideas and satisfaction. The relationships between variables in the sample were explored using simple statistics.

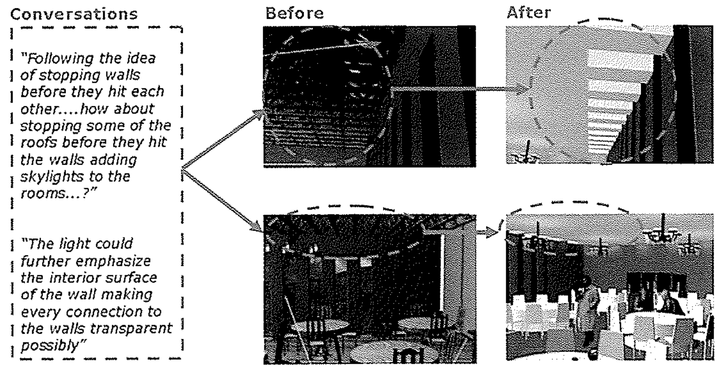
Findings from content analysis

Three cases of the online chat help to explain how the students applied shared tacit design knowledge to their design projects.

Student 1: Professional Recommendation

Student 1 is a 24 year-old male student with 9 months practical experience as an architectural intern in an architectural firm in the U.S. The questionnaire data indicates that he had the lowest usage of CMC technologies as compared to the other students. He had not used CMC technologies such as chat, instant messaging, and groupware for design projects at all. On the other hand, his data revealed the highest knowledge gathering attitude compared to the other students. He was also very interested in receiving critiques about his design concepts from practitioners in the industry.

Figure 4. Student 1 example



A reviewer made a comment suggesting a different ceiling option to possibly add more skylights and enhance the visual quality of the space. Student 1 fully agreed with the suggestion and replied, "That is an interesting option which I had thought about earlier." He was also able to revise his 3D images quickly as shown in Figure 4. This revision indicates a clear illustration of transferring the reviewer's 'generalized tacit knowledge' into 'specialized explicit knowledge'.

Student 2: Identification of Real Problems

Student 2 is a 23 year-old female student with two years of previous practical experience in India. She has never used tacit design knowledge resources for her design projects. She never uses chat, instant messaging or groupware at all. According to the pre-experiment questionnaire data, she prefers to use asynchronized CMC technologies, such as email and Discussion Board. Since she holds a high tacit knowledge gathering attitude, she volunteered to participate in the first chat session.

Quite early in the chat session, the reviewers framed two problems. The problems were the narrow spacing between the buildings and the landscape design for the central garden area. The reviewers suggested creating wider spacing between the buildings. Another reviewer suggested celebrating the central landscaping area, thereby transforming it into a more meaningful space (see Figure 5).

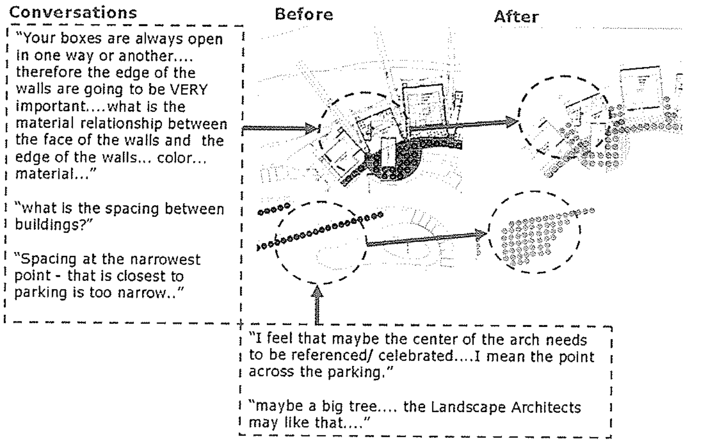


Figure 5. Student 2 example

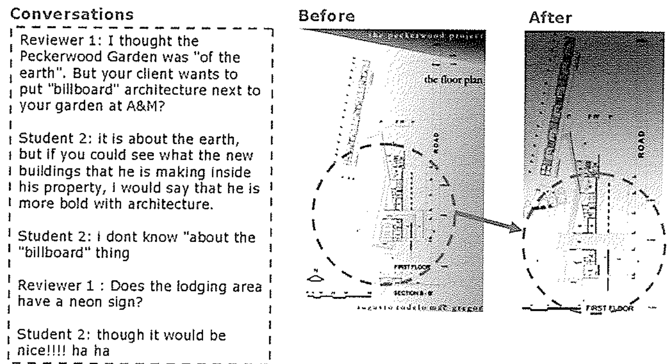


Figure 6. Student 3 example

The reviewers' comments formed the most concrete evidence of the problem. Quickly, Student 2 framed particular problems that would influence the approach to developing a final design. Finally, Student 2 produced a revised floor plan which reflected the comments from the reviewers, as shown in Figure 4. In the end, she decided to integrate one reviewer's comments and changed the drawings. After the chat sessions, her perception of the chat session's usefulness significantly increased from "Not at all" to "Somewhat." Her overall evaluation of the software was the highest level—Very enjoyable.

Student 3: Mismatched Expertise

The following case shows the importance of just-in-time expertise matching. The reviewer is a director of USGBC (United States of Green Building Council), Houston Chapter, who has very extensive knowledge in sustainable architecture design. Student 3 is a person with design philosophy from modern architecture and high-level graphical presentation skills. He is also very positive about adopting technology and has plenty of experience using CMC technologies. However, his knowledge gathering attitude indicated "Not Very Much," according to the 4-point Likert scale.

In the chat session, Student 3 and the reviewer began the discussion from different perspectives and philosophical standpoints. Even though Student 3 did not seek advice from "green architecture" perspectives, the reviewer suggested an alternative decking option, composites, woods, and recycled plastics. The suggestions about the materials were not attractive for the student since they do not carefully consider the materials in a conceptual design stage. Although the reviewer has vast knowledge about sustainability, the student did not recognize the significance of sustainability for the project.

Although they spent much time discussing sustainability, Student 3 did not incorporate the comments into his project, as shown in Figure 6. Content analysis of this chat session suggests that just-in-time expertise matching, and a higher sense of cohesion might be very strong enabling factors for sharing tacit design knowledge in a distributed design environment. In the words of Student 3,

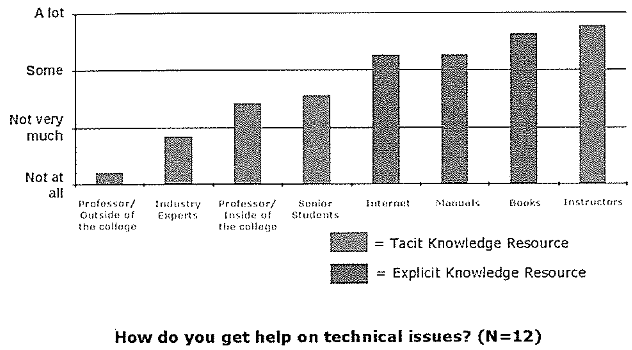


Figure 7. Technology usage

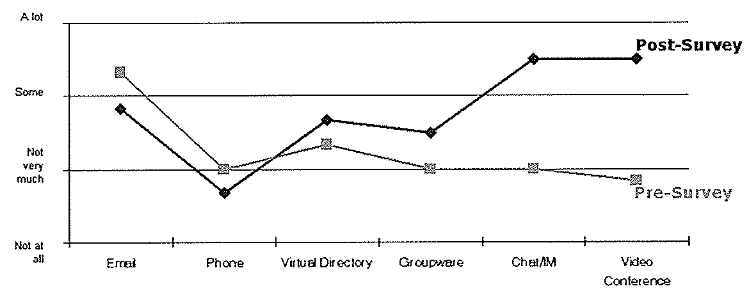


Figure 8. Perceptions of the integration of CMC technologies in design studios

"Experts need access to the history of the project such as who is the client, what are the goals, what skills or knowledge do the various students (or agents) bring to the project."

Findings from quantitative data

The analysis of the questionnaires and the log files is described in order to answer the following question, "How does the software assist in capturing and sharing tacit design knowledge?" In the questionnaires, most participants reported that their experience with the software was very enjoyable and the software is well-designed to support sharing of design knowledge. Participants indicate clear expectations that synchronous chat could be integrated with visual display, such as "mark-up systems."

Figure 7 illustrates that the students primarily use explicit knowledge sources such as the internet, manuals, and books when they need help on technical issues. Tacit knowledge resources, such as industry professionals, professors, and senior students, are not favored knowledge resources, even though they could provide very valuable knowledge. Instructors are definitely the most trusted resource since instructors assign grades.

The students varied in their perceptions of the integration of CMC technologies in design studios. The questions about CMC technology perceptions were asked twice in both questionnaires. Figure 8 shows the difference in the perception of CMC technology before and after the experiment. The perception of phone, groupware, virtual directory, and email stay the same. However, their perception about chat/instant messaging and video conferencing was greatly improved as shown in Figure 8. The results suggest further that students recognize chat/instant messaging as an opportunity to share tacit design knowledge and interact with others, not as a communication medium in which they only strive for facilitating faster communication.

Data from the questionnaires were used to evaluate the software and to consider how the software could be improved and implemented in a distributed design environment. Table 2 shows students' answers regarding their satisfaction with DKM. Significance statistics are not reported for the data due to the small sample size.

Overall, how would you describe your experience on the software?	Very enjoyable	2	2	2	0	0	0	0	Very frustrating
How would you describe your experience on the chat sessions?	Very enjoyable	2	2	2	0	0	0	0	Very frustrating
How would you describe your experience on the chat archives?	Very enjoyable	0	1	1	4	0	0	0	Very frustrating
Overall, is the software well-designed to support sharing of design knowledge?	Strongly Agree	0	4	2	0	0	0	0	Not at all
Overall, do you think that the software is useful to improve your design project?	Strongly Agree	1	2	3	0	0	0	0	Not at all

Table 2. Number of Answers from the post-experiment questionnaire

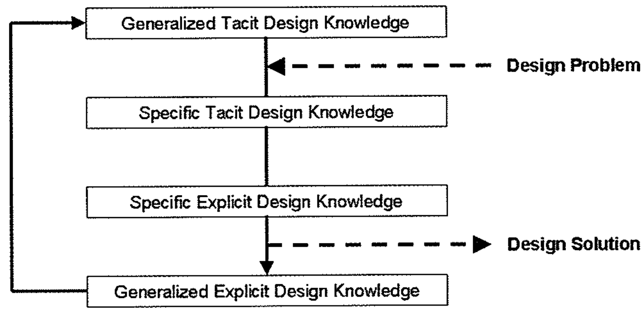


Figure 9. Theoretical Model Development

Overall, all respondents reported that they would consider using the software for sharing design knowledge in their next design studio. Student perceptions of chat were very positive. On a scale of 'Frustrating' to 'Very enjoyable,' all students answered with favorable ratings. Most of them reported that their experience with the software was very enjoyable and that the software is well-designed to support sharing of design knowledge (see Table 2). Students expressed that the chat sessions were very enjoyable, although some basic user interface issues had not yet been resolved (for example, screens were continuously refreshed and the chat thread could not be read). However, these data indicate that participants were very satisfied with the functionality of the software in terms of knowledge sharing.

Theoretical Model Development

The initial theoretical model was modified and extended as a theoretical model for design knowledge sharing process by formulating the research results (See Figure 9). Design knowledge sharing is initiated by applying 'generalized tacit design knowledge' to a specific design problem. When the students talked with their design critiques to acquire tacit design knowledge, the design critic's generalized tacit design knowledge may become 'specific tacit design knowledge' with the consideration of a specific design problem.

The students then convert specific tacit design knowledge into explicit formats, such as sketches, models, and drawings. Although those explicit expressions are often inadequate to fully articulate tacit design knowledge, it is a typical process of reflective practice in the design profession (Schon 1983). And then, the students and design critics update 'generalized explicit design knowledge', such as existing databases and codified information resources. Finally, the above experiences are accumulated as 'generalized tacit design knowledge' in the form of shared mental model or technical know-how (Nonaka and Tacheuchi 1995).

Conclusion

This paper addresses the needs of CMC strategies to share and reuse tacit design knowledge in a distributed design environment. Literature initially offered a theoretical background that the AEC industry could extend into a specific theoretical model for design knowledge sharing process. The case study then provided evidence that tacit design knowledge can be shared and reused by using chat-based CMC strategies.

In the experiment, the online chat was useful in sharing professional recommendations, intuitive expectations and past experiences. The participants easily identified well-defined design problems, thus enhancing conceptual design. Finally, the initial theoretical model was then extended as a theoretical model for design knowledge sharing process by formulating the research results.

The findings presented in this paper increase our level of understanding about the implications of tacit knowledge sharing. The results indicate that the synchronous chat sessions positively influenced design performance by virtue of tacit knowledge sharing. Student perceptions about the software were also very positive. All students would consider using the software for sharing design knowledge in their next design studio.

This research also suggests that tacit design knowledge may be confidently shared and reused through careful strategic implementation in a distributed design environment. Content analysis and demographic and attitudinal surveys of the participants suggest that enabling factors for sharing tacit design knowledge include knowledge sharing attitude, strong top-down management support, just-in-time expertise matching, CMC technologies support, and higher sense of cohesion. Strong management support and commitment from leadership can provide direction for knowledge sharing strategy.

Limitations

The analysis of some responses from the open-ended questions revealed needed improvements in the software development for more comprehensive design knowledge communications. Several reviewers pointed out that participation would have been greater and the measurable contribution could have been much greater, if the design project had begun using this interface in an earlier stage. The maturity of the project discussed in the chat sessions was the major barrier to this research. There are few suggestions on the time schedule for the chat sessions. They describe a successful use of chat but found it difficult to arrange chat schedules. They want to schedule more chat sessions with longer timeframes to form a more cohesive group. The students felt that the reviewers needed more time to understand the history and background of the projects.

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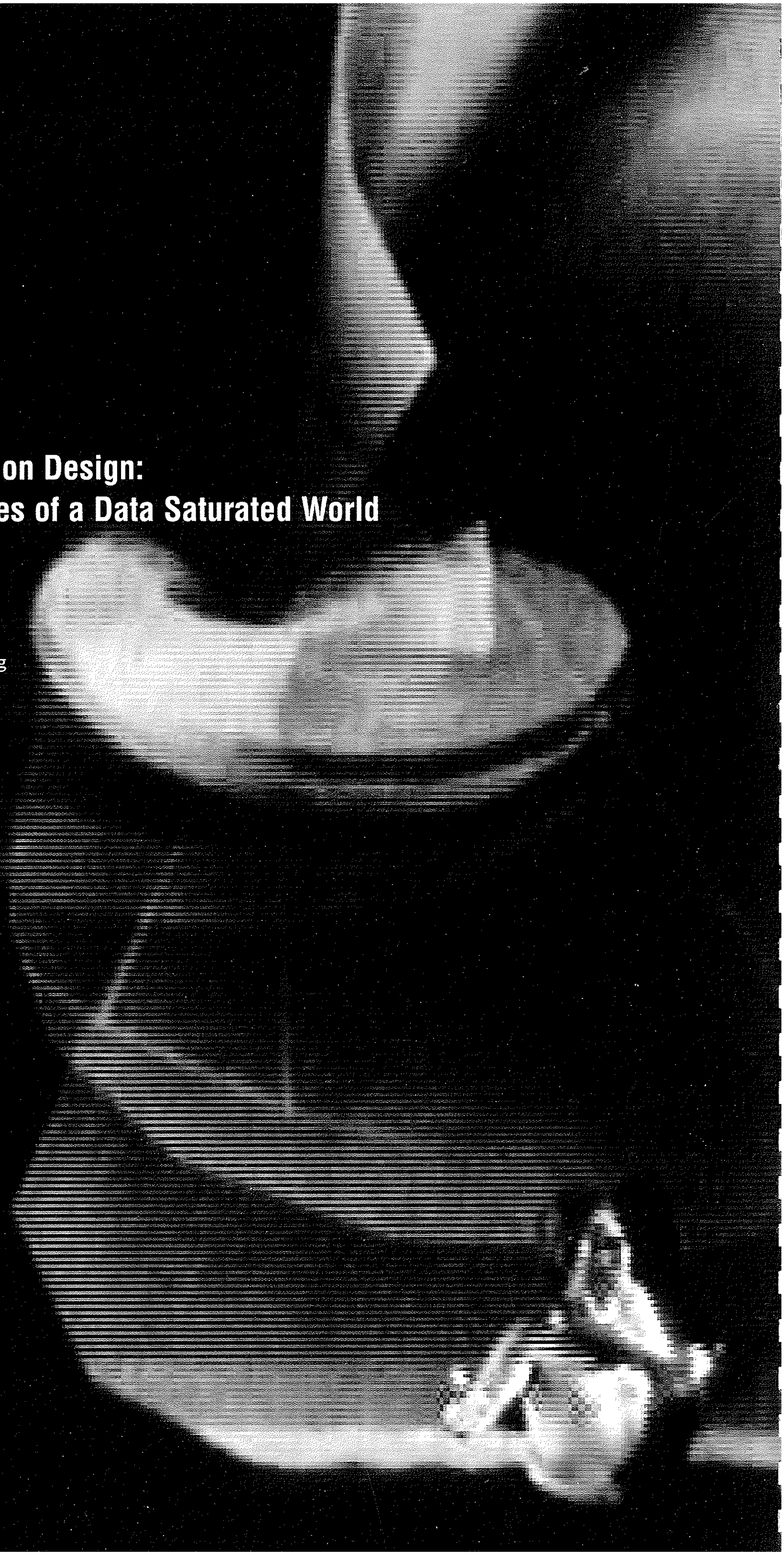
Information Visualization Design: The Growing Challenges of a Data Saturated World

Jim Agutter
Julio Bermudez
College of Architecture + Planning
University of Utah



We are living in a world overflowing with information.[1] Millions of labs, apparati and scientists across the planet are continuously conducting millions of experiments, observations, and analyses producing huge amounts of data. Our ordinary lives have become data traces too: the ATM transaction, the online registration of our new software, the credit card purchase at the mall, the cellular phone call, etc. The security concerns of late have only exacerbated this need for and accumulation of data. In this reality, the central issue has shifted from getting data to making sense of it.

Over 20 years of work in Scientific Visualization, Human Factors, and Semiotics indicates that there exists a direct correlation between how data is represented and the meaning we can extract from it. Better representations mean better understanding. In fact, *the way* that data is presented has an overwhelming weight in how a system or situation is perceived and what ultimately drives the decision making process.[2] Currently, there is wide agreement that *visualization* is the best representation method for turning complex data into information.[3]

Although there has been much work in the visualization design area, we are only beginning to tap the possibilities of communicating data visually. There have been many well documented examples of inappropriate decisions based upon information that was presented poorly (e.g., from the Harrisburg nuclear plant crisis in 1979 to the Challenger and Chernobyl disasters in 1985 to the breakdown in intelligence sharing leading to 9–11). Yet, more negative impacts may be found in less spectacular but more pervasive errors found in day-to-day information driven operations (e.g., medical services, process control management, network monitoring, business operations, and so forth).[4] The reason for this worrisome state of affairs is our persistence in using early twentieth century quantitative methods, naïve notion of human cognition, and simplistic representation spaces when battling data environments of twenty-first century complexity. We just cannot keep doing this any longer and expect good results. A good example of the prevailing and limited paradigm in information visualization is shown in Figure 1 on the following page.

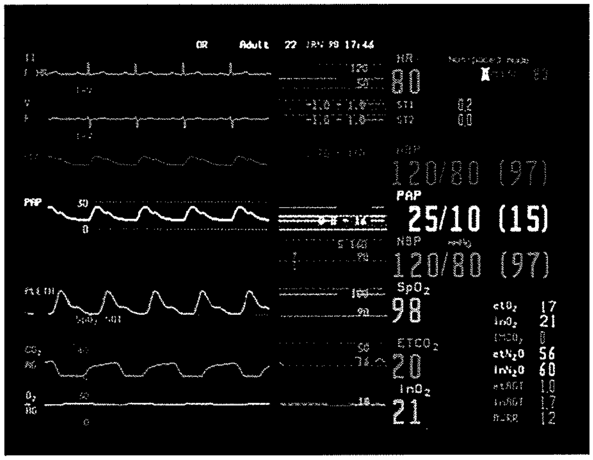


Figure 1: Current display of physiologic data in Anesthesiology (Datex-Ohmeda). Traditional representations are characterized by numerical-waveform (as opposed to geometrically graphic), discrete (as opposed to integrated), and non-interactive data representations. Shortcomings include (1) not grouping of variables in cardiac and pulmonary sub-systems, (2) providing no priority and hierarchy to variables, (3) recognizing no functional relationship of variables, (4) color and other design attributes serve no particular meaning, (5) its unintuitive nature takes year of training to master; and as a result (6) experts (i.e., anesthesiologists) have the cognitively demanding and error-causing task of associating the variables in real time to correctly diagnose clinical scenarios

The present shortcomings of data representations can be traced back to the fact that most information visualizations have been produced by scientists and engineers, whom are trained in quantitative and not qualitative methods, in analytical and not integrative processes, in obtaining or using and not communicating knowledge. The data representation challenge confronting today's scientific and engineering communities may be summarized as follows:

> "Instead of concentrating on building more and more elaborated systems of rules, there must be an effort to accommodate the innate and vast human perceptual capability. The deficiency in many computer graphics presentation is not in the output volume, but in the display itself. More intelligent computer programs are not needed, but more intelligently-designed computer displays are"[5]

New approaches that enable data-based decision making to be *faster, more accurate*, take *less cognitive effort*, and require *less training* are needed. We need information visualization systems that *also* address the qualitative and symbolic dimensions intrinsic to all decision making process. It means to transform raw data into information through a refinement process called selected depiction. Pursuing this work demands the interdisciplinary collaboration among art, design, science, and technology.

On Data Representation Architecture & Interdisciplinary Collaboration

For over 8 years, our research group, CROMDI (Center for the Representation Of Multi-Dimensional Information, http://www.cromdi.utah.edu), has been working on the display of information in five domains: Anesthesiology, Finance, Process Control, Network Security and Monitoring, and Live Art Performances. Our goal has been the development of a new generation of *data representation architectures* that offer a better alternative to the existing status-quo in information visualization. We *define data representation* architecture as the organizational, functional, experiential, and media-technological order defining the interaction between data, representation, and user. Although our research group is composed of people from a variety of disciplines (e.g., Business, Computer Science, Mathematics, Medicine, Music, Psychology, and so forth), it is Architecture that has taken a decisive leadership role at the managerial, conceptual, and productive levels of the interdisciplinary effort.

Our experience has taught us that certain methods are more conducive than others in supporting interdisciplinary collaboration. Among them, three essential practices are at the heart of our approach and methodology:

(1) the pursuit of a committed and sustained *complete interdisciplinarity*,
(2) the utilization of the *design process* as the basic engine of its interdisciplinary methodology, and
(3) the application of *built-in evaluations* throughout the process as a quality control mechanism that feedbacks directly into the design development.

Architectural Relevancy & Interdisciplinary Collaboration

The relevance of *architectural research* to the design, construction and communication of data spaces has been supported by the leading minds in Architecture as a natural extension of designing and building functional forms and spaces.[6]

Our experience has taught us that there are four core architectural competencies that make our field especially relevant to information visualization:

(1) proficiency in representation, simulation, and communication;
(2) a developed knowledge base in formal semiotics;
(3) fluency in the management of multiple disciplines, technologies, and individuals toward achieving a goal, that is traceable to our design studio environment and master builder/ leadership training; and
(4) expertise in the employment of the design process as research methodology to solve ill-defined and difficult problems.

(1) Representation expertise

Architecture has a centuries-old expertise in the representation, simulation and communication of diverse and often complex types of information. There is also a long tradition of architects using depictions to conceive the not yet built and speculate about impossible architectures and utopian environments.[7] The recent full adoption of digital media (with its cross-disciplinary technological reach) gives architecture the potential to extend this expertise and visionary skills to other domains, notably in the creation of data environments wherein representation and imagination rule the day.

(2) Formal semiotics

Architects ordinarily deal with the syntax, semantics, and pragmatics of 2D and 3D form and space. As a result, the discipline has collected a comprehensive knowledge base of the nature, methods, and value of basic (i.e., abstract, geometrical) 2D and 3D design and their relationship to human collective and individual psychology and behavior (i.e., meaning and use). This knowledge base consists of basic principles (e.g., scale, shape, rhythm, color, structure), elements (e.g., line, figures, objects, space) and organizational rules (e.g., hierarchy, layering, symmetry)[8]

The architectural expertise in formal semiotics and representation lays the ground for developing graphic conventions (syntax) to successfully encode (and decode) data parameters into representations (semantics and pragmatics). They also prove resourceful when considering the economics of data processing, that is, the hardware and software inherent limitations in dealing with complex dynamic databases. It is natural for our discipline to take a leadership role in advancing the state-of-the-art of information visualization.

(3) The Studio Model & the Master Builder

Training Supporting Interdisciplinary Research Developing new data representation architectures demands responding to many intertwined issues. Not only must we have some cognitive model of the user's data-driven decision making process, but also determine the nature and behavior of the data (structure, process), the type of problem, needs and requirements, and the technology to deliver such depiction. Clearly, this cannot be done by architects alone. In fact, this task would overwhelm any single discipline by its sheer complexity, scale and multi-dimensionality. Nothing less than a well organized interdisciplinary approach will do. Bringing together the expertise of different disciplines provides the necessary tools to address this challenge.[9]

However, carrying out interdisciplinary collaboration is not easy. It requires a careful structuring of group dynamics, so that they are based on clear roles, respect, trust, values, shared goals, and a common language.[10] Here the tolerant yet critical and productive *architectural design studio* becomes remarkably useful. The *studio model* offers a real intellectual and physical environment for conducting inquiries engaging multiple viewpoints in cross fertilization, discussion, and production. Under such interdisciplinary collaborative conditions, we have discovered that architects are able to function as mediators and brokers of knowledge and ideas across domains with an ease and effectiveness not matched by others. This is due to the architects' master builder training that gives the ability to organize, communicate and coordinate disparate efforts into a coherent whole without loosing track of the goal. Not surprising, it is the architecture team, within our larger interdisciplinary group, leading the research efforts.

(4) The Design Process As Interdisciplinary Research Methodology

Our expertise in using the design process as a methodology for discovering, developing, and testing hypotheses is yet another reason behind the leadership and relevance of architecture in information visualization.

Adopting the design process as our interdisciplinary methodology naturally evolved during the first two years of research work. We determined that effective information visualization tools for decision making are better if developed with an iterative design process that permits simultaneous attention to multiple perspectives, skills and knowledge-bases. We also found that the *design process* allowed for a spontaneous and natural way of socially engaging a wide range of disciplines and individuals working in a very difficult problem. This is in line with existing knowledge that the *design studio model* in general and the design process in particular are a successful working laboratory and methodology for addressing open-ended, fuzzy, and multivariable problems.[11] Although this may not seem like a surprising finding for architects, it was indeed an important realization for those coming from other domains. We will describe the results of our data architecture work in three distinct areas: anesthesiology, computer network security, and live performance.

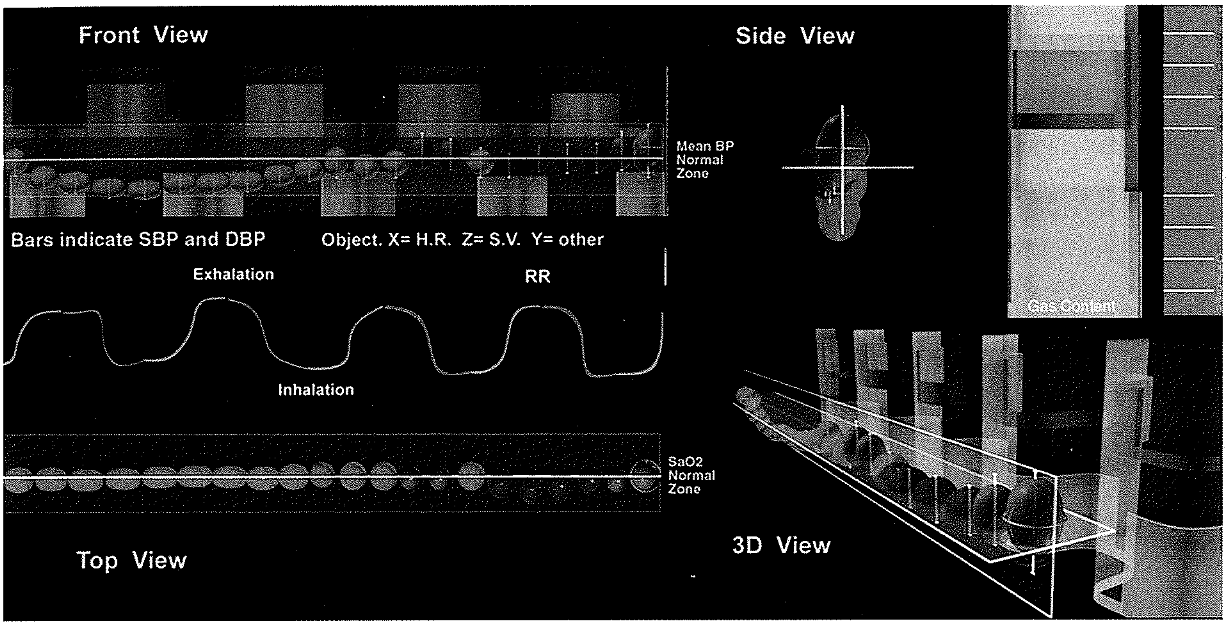


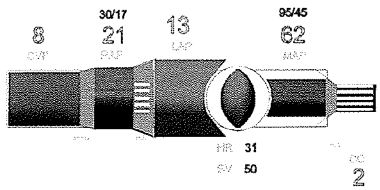
Figure 2: CROMDI's visualization system for displaying physiologic data in real time. (© copyright 2000 CROMDI, all rights reserved). Spherical object represents cardiac variables, Stroke Volume, Cardiac Output, and Heart Rate. Each ellipsoid shows the efficiency of a heart beat; deformations from normal spherical shape show non-optimal efficiency. Movements up and down allow the association of the state of that object (and its variable relationships) to Blood Pressure. Similarly, by establishing a figure-ground relationship with the "curtain" object (in the background) that integrates respiratory data (Tidal Volumes, Respiratory Rate, Nitrous Oxide, Oxygen, etc.) and by incorporating color to depict Arterial Oxygen Saturation into the spherical object, there is an immediate perceptual realization of the health state of both essential physiologic functions. Compare to existing display shown in Figure 1.

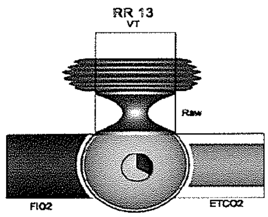
Project Description and Results

Anesthesiology

Anesthesiologists face unexpected incidents during 20 percent of all anesthetics. Human error is associated with more than 80 percent of the critical incidents and more than 50 percent of the deaths.[12] Many errors can be directly traced to erroneous or misleading information from monitors or in the physician's failure to recognize a pattern in the data that would have led to a correct diagnosis. The environment is stressful and the task is difficult because 30 variables need to be monitored and mentally integrated. Anesthesiology displays use a single-sensor single-indicator paradigm that is an addition to the strip chart recorder output Sir Thomas Lewis used in 1912 for the first ECG (Figure 1).

Clinicians must observe and integrate information generated by the independent sensors to observe significant changes. This process of sequential, piecemeal data gathering makes it difficult to develop a coherent understanding of the interrelationship between the presented information of physiological processes.[13] In order to address these matters, we worked for five years to develop displays for detecting, diagnosing and treating anesthesia related critical events that significantly reduce recognition times. Our data visualization solutions offer a fundamental departure from the way the medical field presently detects, diagnoses, and treats physiologic conditions. For example, Figure 2 shows our first completed data representation design attempting to offer a holistic view of the two major physiologic functions (cardiac and pulmonary) that need monitoring during anesthesia.





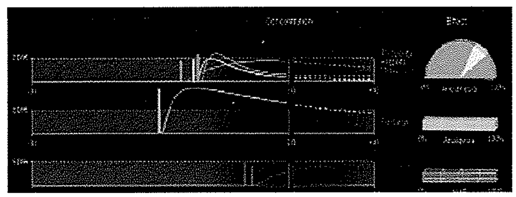


Figure 3 (left): Cardiovascular Data Display. Figure 4(Middle); Pulmonary Data Display. Figure 5 (right): Drug Data Display.

Figures 3 through 5 show our design efforts to develop physiologic data displays presently not available to physicians and anesthesiologists and which may result in significant improvement in high-risk medical services. Figure 3 shows our *Cardiovascular Data Display*. This design organizes measured and modeled cardiovascular information variables showing functional relationships and including concepts such as preload-afterload. Figure 4 presents our *Pulmonary Data Display*. This visualization design offers respiratory data about patient and ventilator while showing functional relationships and essential gas exchange information. Figure 5 portrays our *Drug Data Display* that delivers dynamic representations of pharmacokinetic behavior while offering prediction information and historical trending. These displays because of their holistic rather than isolated view of patient variables will have a positive impact in the current delivery of anesthesia.

Thorough scientific evaluations of CROMDI physiologic data displays have showed statistically significant improvements in performance in several critical scenarios when compared to performance utilizing traditional/existing data displays.[14] For example:

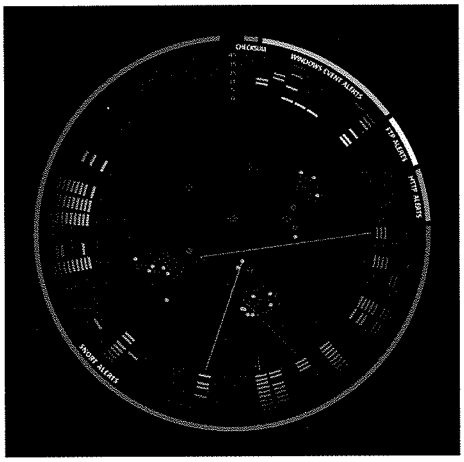
- Clinicians detected anesthesia-related critical events sooner (3.1 vs. 5.5 min),
- Abnormal events were diagnosed more accurately (error rate 1.1 percent vs. 4.1 percent),
- Problems were corrected in one-third the time (17 sec vs. 45 sec), and
- Drug delivery was better controlled (EC95 error 21 percent vs. 44 percent).

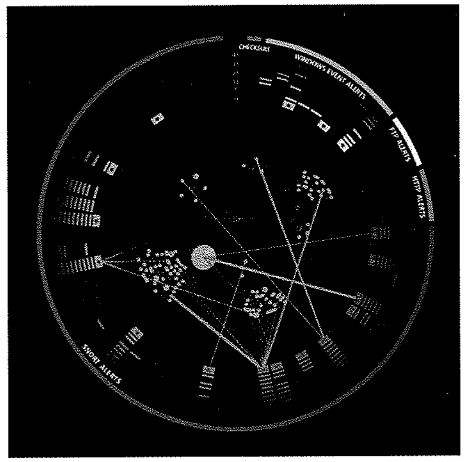
Computer Network Intrusion Detection

The goal of this research is to develop a new generation of cyber-security visual displays that integrate distinct advances in data representation design, cognitive psychology, computer visualization, with heuristic knowledge and statistical methods from cyber-security experts, to significantly improve network analysts' and decision makers' ability to discover, diagnose and rapidly respond to critical cyber situations.

The state of the art in network monitoring is to present streams of abstract data (e.g. system logs, packet loss, intrusion alerts) with plots, pies, bars, maps, trees, and so forth (e.g. Fig. 2). Displays based on these centuries old metaphors do not reflect the relative importance of the variables and the evolution of the relationships; they do not capitalize on the power of modern computer graphics and on human natural perception; also, they have limited ability to convey insight from the increasing amount of data produced today. Sifting and integrating through screenfuls of such displays may produce information overload, which is a common complaint in this field and may not allow for analysts to see important patterns or trends. When faced with multi-variate information, decision makers develop their own heuristic rules and mental models for selecting and integrating information, which may take years of training or experience. In other situations, decision makers need intermediation by experts: this introduces layers of reliability loss and time delay, which interfere with mission criticality. In many cases, this results in suboptimal performance and human error. There is a need for tools that augment human ability to draw insight from abundant or complex data, in order to make decisions: *faster, more accurately*, with *less cognitive effort*, and with *less training*.

By delivering visual metaphors standing for assets, events, contexts, relationships, complexity levels, reliability, relevance, priority, and so forth in a dynamic reference to infrastructure, strategy, and tactical considerations, our design methodology fully exploits humans innate and vast cognitive abilities to recognize patterns and establish high situation awareness, resulting in substantially enhanced decision-making. Such an approach represents a radical shift from current network visualization using plots, graphs, bar charts.





left to right:

Figure 6: VisAlert Display left showing normal network traffic

Figure 7: VisAlert Display showing an intrusion attempt on machine with large circular node

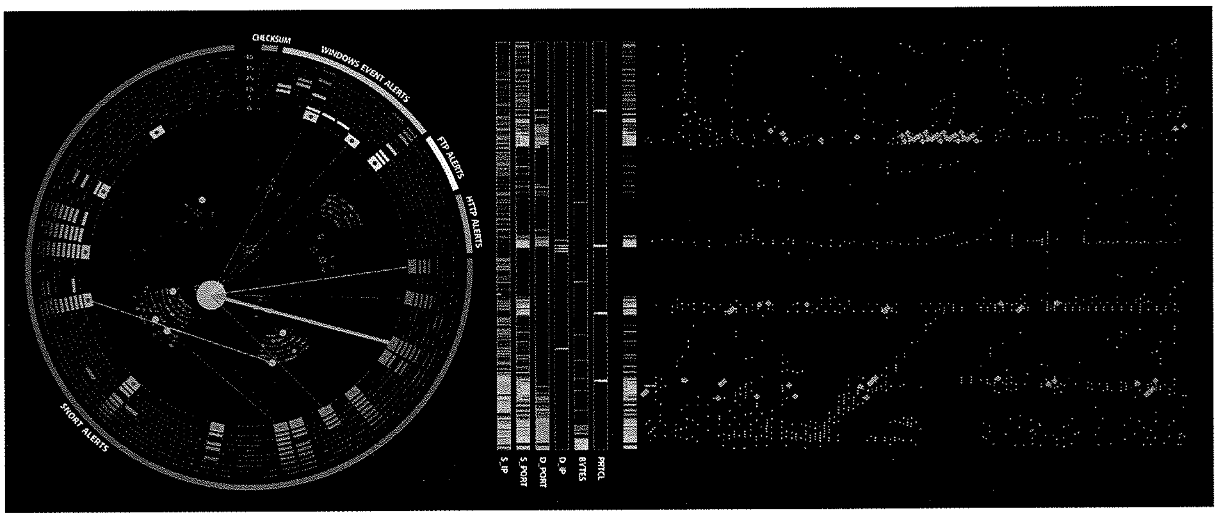


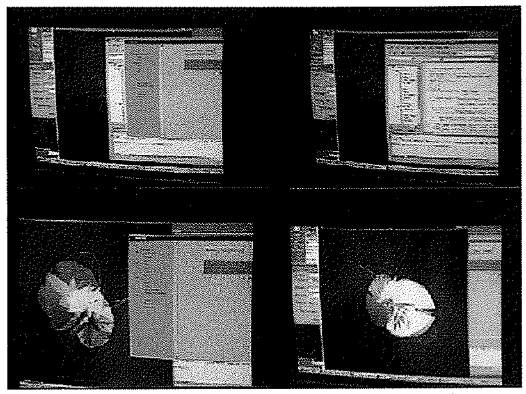
Figure 8: VisAlert Display showing 3 visualization modules. The leftmost display shows host and network based alerts around the ring and mapped to network topology. The waterfall display in the center shows a summarized view of network traffic associated with selected network nodes. The analysis view on the right shows a detailed view of the waterfall with time expanded in the X dimension. This work is © copyright 2003-05 by CROMDI, all rights reserved.

Visualization concepts

We developed three separate visualization modules that provide the user with different ways to view network related data. These visualization modules allow for the visual correlation of different logs from computer systems across an enterprise for the detection and diagnosis of complex intrusion attempts. These displays provide a view "at a glance" of the number of different types of alerts associated with machines across a network. This processed data (alert set) then provides the capability to drill down into particular aspects of the data to see patterns over a variable amount of time. The user then has the capability to interact with refined views of the data and configure different comparisons in the analysis. These views can then be saved and compared that may reveal attack signatures. The user also has the capability to enter notes about particular nodes that can be accessed by others as a way of sharing information. In summary, the visualization allows for the following benefits: data fusion of disparite data sources, data drill down, a holistic view of overall network activity, and pre-attentive design that takes advantage of innate human perceptual qualities.

Figure 9 (left). Choreographer Yacov Sharir (University of Texas at Austin) trying out the cyberPRINT technology.

Figure 10 (right). Screens of software running the project



Live Art Performance: The cyberPRINT

Our group has successfully developed the cyberPRINT, a live art production that has been performed more than 20 times nationally and internationally since May 2000. The cyberPRINT covers a wide and fertile territory that goes from the very technical and design/art oriented to the very theoretical and interdisciplinary.

The cyberPRINT is an electronic bio-feedback system driven by physiologic data drawn from a performer via special sensors attached to the body and transmitted wirelessly to computers which, in turn, generate and project a specially designed and programmed audio-visual 3D virtual reality in real time. Since the resulting virtual artifact represents the individual whose biological data generate and sustain it, it is a cyber-PRINT or personal signature of that individual in digital space. By enveloping its user through screen projection and/or virtual reality technologies, the cyberPRINT allows that individual to visualize, inhabit, and interact with themselves and others in unimaginable ways.

Great research effort was devoted at creating interfaces between biology and information technologies. Although we utilize existing technology to wirelessly obtain the data from the body, we had to develop our own hardware and software tools to be able to utilize those signals in the ways required by the project. The physiologic data is gathered from non-invasive medical sensors registering vital signs in real time in numerical data format (i.e., EEG, ECG, EMG, EOG, and PSG signals). The measured data is sent via radio signals directly to a PC where they are then pre-processed and immediately sent to another computer with special software to generate the cyberPRINT.

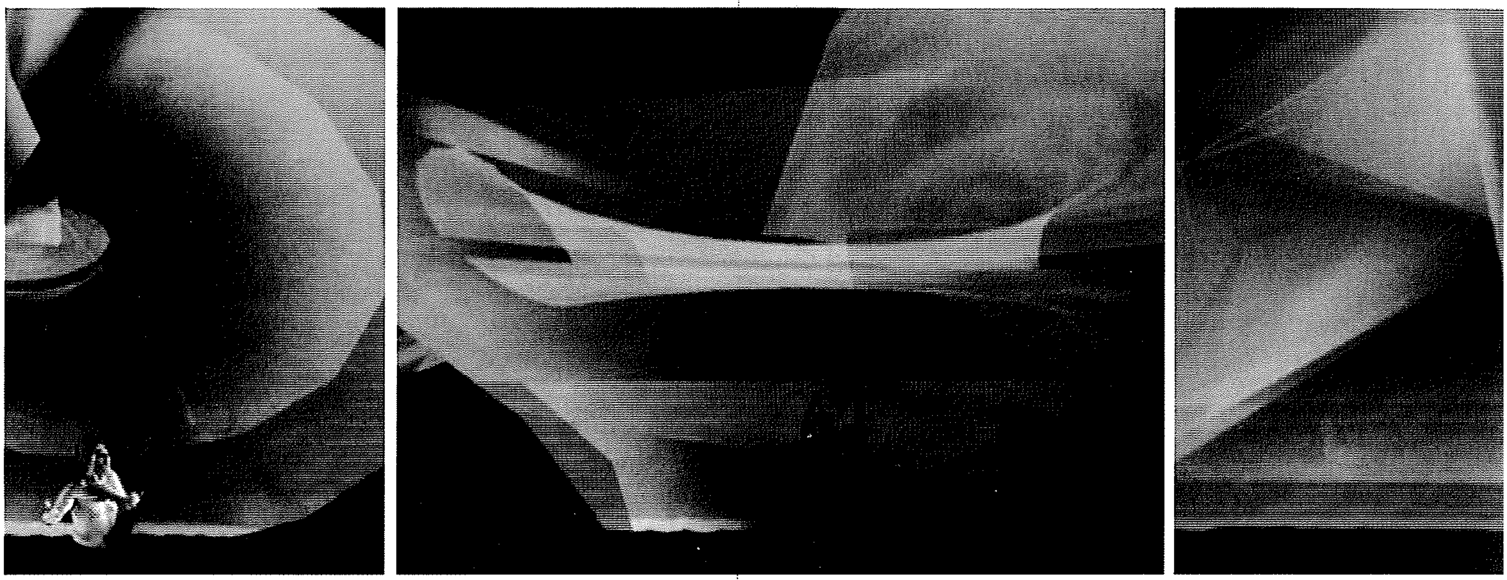


Figure 11-13 Three still video captures from live performances with Yacov Sharir (circa 2000-2002)

By making the body the hinge point where virtual and physical spaces meet and interact (i.e., the virtual is generated by the real, but the real is affected and changed by what the virtual does), the cyberPRINT casts new light into what has become ordinary for most individuals today, the coexistence of virtual and physical spaces at once. More intriguingly, it opens up the consideration of what may be called an "*architecture of being*" *that manifests anew the actual fluidity of the self in real time.* In doing so, this project offers a new understanding and expression to the ancient artistic quest of depicting the self and the body.

The cyberPRINT completely owes its existence to the interdisciplinary collaboration among architecture, bioengineering, medicine, computer science, choreography, modern dance, and music. In 'exchange' for this effort, the project has played an instrumental role in infusing impetus, creativity, and excitement to our overall research agenda. In fact, many new scientific, technological and design insights have been conceived and implemented *because of* the artistic development of the cyberPRINT. It is also clear that the research, design, and performance of the cyberPRINT have expanded the conceptual, aesthetic, and technological boundaries of architecture.

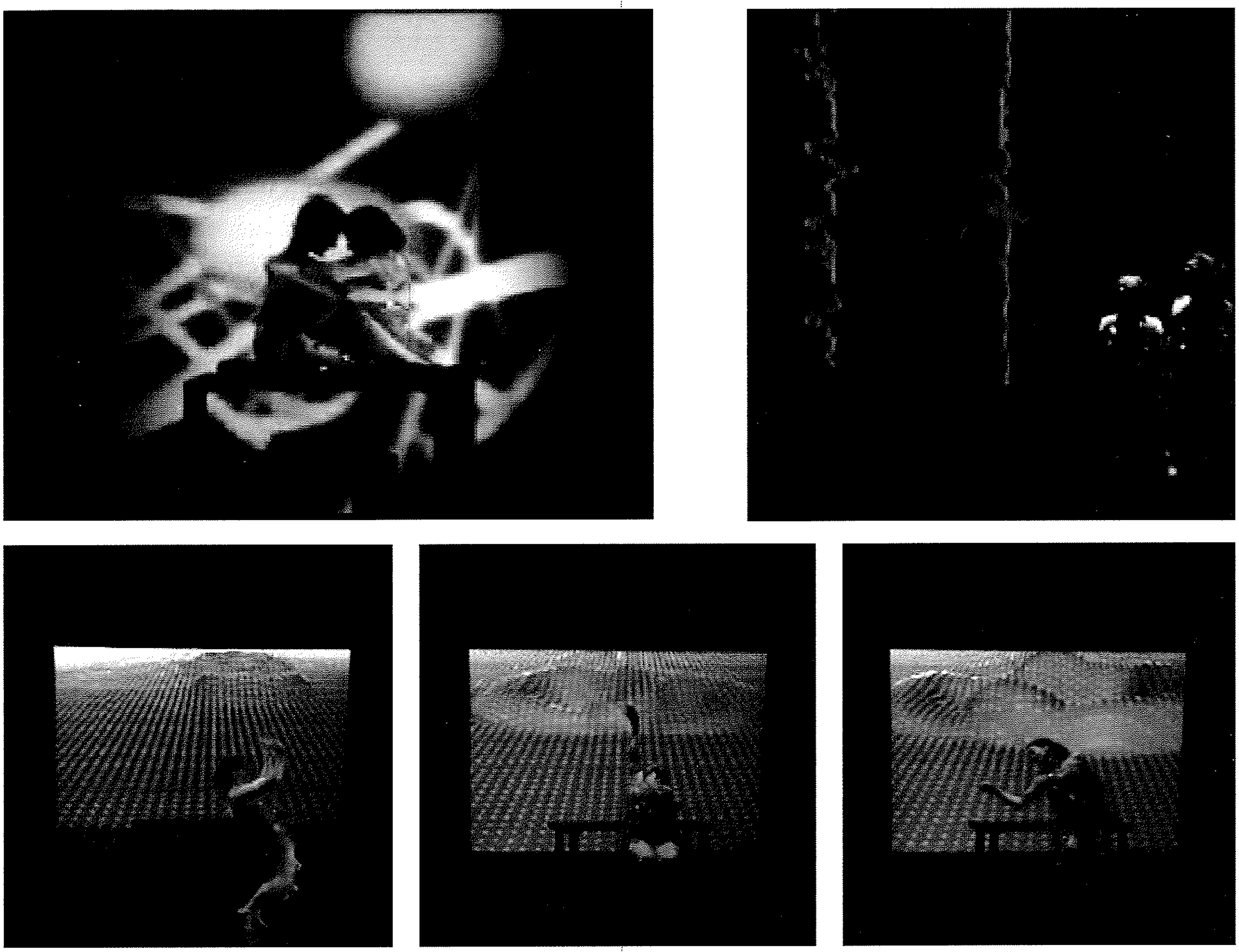


Figure 14 - 19: Five still video captures from last live performance at Oberlin College in May 2004. Collaboration with Oberlin College faculty Nusha Martynuk, Carter McAdams, Holly Handman and Tom Lopez

Conclusion

As our civilization dives deeper into the information age, making sense of ever more complex and larger amounts of data becomes critical. In order to respond to this challenge, we profess a new architecture made out of data, fluctuating with its rhythms, occupying digital space and aimed at improving the decision making of its users—who spend several hours a day dwelling in its midst. We call it data representation architecture. Manifesting this belief into a full-fledged interdisciplinary research effort has proven laborious but extremely rewarding. Succeeding meant to overcome these challenges (several of which we continue to face):

(a) Accommodating different methods, techniques, positions, interests, standards, languages, perspectives, knowledge, and so forth of our members' diverse disciplines.
(b) Working within a university structure that does not encourage interdisciplinary work because it doesn't fit traditional academic and administrative boundaries.
(c) Convincing funding agencies, peers, and journal publications of the value of interdisciplinary work in the face of a widespread attitude that working across fields is less scientifically rigorous (or suspect design-wise).
(d) Struggling through disparities in salary and academic recognition among the different disciplines.

Despite these challenges, we have been very successful at designing, building, and testing information visualizations supporting real time decision making in anesthesiology, finance, process control, live art performance, and network monitoring. These information spaces display data in a format that makes best use of human natural perceptual abilities. Rigorous scientific testing has demonstrated that 'dwelling' in such data representation architectures allows people (i.e., anesthesiologists, traders) to make more accurate, faster, and better decisions than with existing systems. Indeed, they can do so while with reducing their cognitive load, stress, and training time.

The success of this enterprise is proven by the longevity of our group (8+ year long), over $4.7M in grants (from the NIH, NASA, DARPA, ARDA, State Centers of Excellence, and private industry) and a very prolific productive record with over 50 articles published in 4 fields, several pending patents, a spin-off company, 3 commercial licenses and more than 20 public live art performances in 3 continents. The recent commercialization of our information visualization technology in Medicine means that our work will soon find its way into operating rooms, intensive care units, and other medical environments for the benefit of society at large.

Such accomplishments, as well as the role of architecture in leading this interdisciplinary effort, educate the university environment regarding the significant role that architecture may play in advancing the cause of science, technology, and academia at large. As important, it demonstrates the value of architectural education and inquiry to our own students, practitioners, scholars, and administrators. In doing so, this research work expands the existing boundaries of architectural research while offering a valid example of alternative architectural practice. It also shows the potential leadership role that architectural schools and faculty may play in interdisciplinary education and research on campus and beyond.

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Design Guidelines for Adult Day Services

Keith Diaz Moore PhD, AIA
Washington State University

Aging is a relatively new phenomenon in the history of humankind. When this country was founded in 1776, the average life expectancy was 35. By 1900, that had grown to only 47 years. Currently, the average life expectancy is 77, and for those that today are turning 65, they can anticipate celebrating their 83rd birthday.[1] This phenomenal growth in life span is raises challenging issues for our society; issues that are both social and medical in nature with significant ethical underpinnings.

How do we care for our elderly? Initially, in our agrarian society, the aging were taken care of by loved ones. With industrialization, families became geographically dispersed, and with that, when the aging become unable to be productive, either religious homes or county poor farms took care of the indigent. Thus aging was largely a socio-economic problem. This gave rise to the Social Security Act of 1935 which gave public benefits to those 65 years or older, as long as they did not reside in an institution. Simultaneously, many of the issues of normal aging came to be seen as not necessarily normal, but as chronic health conditions (e.g. arthritis), thus "medicalizing" aging. In response to those elderly that could not take care of themselves due to medical reasons, Nursing Homes were created by the Hill-Burton act of 1954.[2] This was an extension of hospital regulations and gave rise to why nursing homes, serving chronic conditions, look and operate like hospitals that are designed to serve acute care needs.

Research in the 1960s and 1970s quickly illustrated the misfit of nursing homes for many elderly residents and a continuum of care settings began to emerge, including assisted living and adult day services.[3] Assisted living has received a significant amount of attention from architectural practice and research over the past 15 years.[4] Yet this model still promotes an institutional model for the elderly requiring assistance. Adult Day Services on the other hand, promotes keeping the elderly in the community fabric, but has flown under the radar within architectural inquiry. This research attempts to rectify this oversight in regard to this intriguing and rapidly-growing model of care.

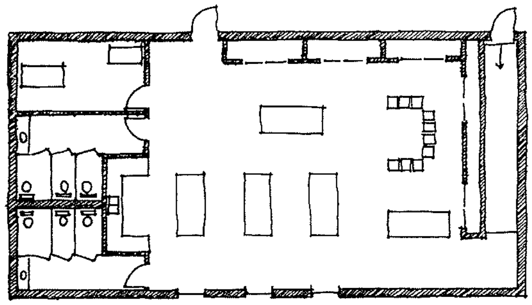


Figure 1. A prototypical floor plan of adult day services located in an actual church basement

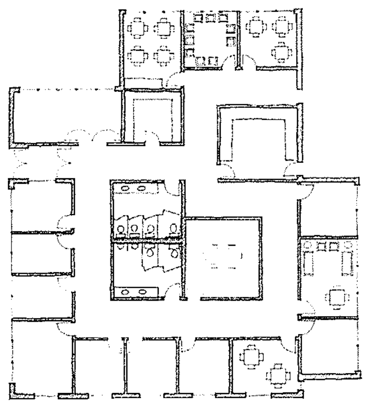


Figure 2. A floor plan of an award-winning facility in a major metropolitan city. Notice the maze-like circulation and the program space that is completely internalized

What is Adult Day Services?

According to the National Adult Day Services Association:

> Adult day services are community-based group programs designed to meet the needs of adults with impairments through individual plans of care. These structured, comprehensive, nonresidential programs provide a variety of health, social and related support services in a protective setting. By supporting families and other caregivers, adult day services enable participants to live in the community.[5]

Adult day services (ADSs) typically operate during normal daytime business hours during the day, generally five (business) days a week, although some facilities provide respite care in the evening and on weekends. According to NADSA, the principal services of ADSs are assessment and care planning, assistance with activities of daily living, health-related services, social services, therapeutic activities, nutrition, transportation and emergency care.[6] This expansive conceptualization is intentional: "the purpose, focus, functions and expected outcomes of adult day programs are so broadly defined as to allow a variety of programs to fit under the adult day services umbrella."[7]

Ironically, the desire to be inclusive may be responsible for both geographically inconsistent growth and increased variability among ADSs. This diversity has had two main effects. First, society has no common expectation of what adult day services are. Secondly, while the rich diversity in adult day services reflects the various strategies that ADSs use in responding and adapting to the needs of participants, it has had the less desirable effect of creating ambiguity among regulatory and funding bodies as well as the public at large. As a consequence of this continual economic uncertainty, "ADSs are in a constant state of adaptation in regard to their funding and regulatory environment. In turn, this environment shapes the delivery of ADS services."[8] The funding stream 'continues to be inconsistent and fragmented what Kane and Kane refer to as "piecework and patchwork."[9] This has historically placed "ADSs in a position of economic uncertainty, focused on survival and maintaining the flow of funding, and on maintaining organizational viability."[10]

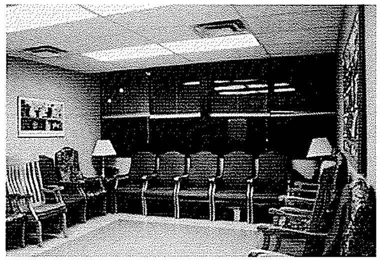


Figure 3. Typical custodial furniture arrangement found in many adult day service facilities

Figure 4. A typical scene in an adult day service facility

However, this is beginning to change. As part of the recently passed "prescription drug benefit," the Department of Health and Human Services was charged with developing a demonstration project to fund adult day services. Currently, both houses of the United States Congress have bi-partisan supported bills pending that will open Medicare "homebound" funding for adult day service participants. It is more a matter of when, than if, this will happen and whenever it does become law, the growth in adult day services will increase dramatically. Why is it inevitable? Because of the cost efficiency associated with Adult Day Services. Currently, the annual cost of nursing home care averages $57,700, or approximately $4800 per month, but for many this is covered by Medicaid. For assisted living, costs vary widely, but average approximately $2000 per month. Golant estimates that only 10 percent of the elderly are able to afford assisted living and that long-term care for moderate income elderly remains a significant challenge.[11] This is the fastest growing segment of the elderly and the population best served by ADS' average daily cost of $46.[12] Given the climate of fiscal restraint, it is only a matter of time before government seizes upon what has been termed "the best kept secret in long-term care."

Not that growth has been slow anyway. Adult day services has roughly doubled every decade since 1980, with there currently being approximately 3400 programs nationally.[13] A recent study suggests an existing unmet need for about 7000 facilities nationwide and one can extrapolate a need of 30,000 facilities by 2050. Given this anticipated growth, it is a good time to critically inquire into how these settings should be designed to be optimally therapeutic for the populations they serve.

The Project

The program of research reported herein was initially funded by the Helen Bader Foundation in 1999 to ascertain the design implications for adult day programs serving people experiencing dementia. Setting the stage for this inquiry was research done for the author's dissertation (funded by the Institute on Aging and Environment and a University of Wisconsin-Milwaukee Dissertation Fellowship) that highlighted the shortcomings in current practice in adult day services. The Bader-funded project had three components: an extensive literature review, development of case studies, and the creation of design guidelines for these settings. This project was completed in 2002 and followed up by a project funded by the Group Health Community Foundation to develop a development process workbook for care providers to become more knowledgeable about this important process in placemaking. Now this assemblage of information has been translated into a book, *Designing a Better Day* in press with Johns Hopkins University Press.[14] This report for the AIA highlights two of these aspects: the current state of design of adult day service settings, and the design guidelines.

The State of Design of Adult Day Services

The current state of design for adult day services is easily summarized by the word "impoverished." As you can see in Figures 1 through 4, both the interiors and the plans are not creatively developed and lack any sense of responsiveness to the needs of the populations which they serve. Yet these are all designed by registered architects. How could this be?

Because of their ill-defined nature, adult day services are very difficult to design. There are not very many good precedents and even if one finds a good precedent, the exact population mix and programming of the adult day service may be quite different. Adult Day Services accommodate a wide range of activities, which we have distilled into eight recurring "Realms of Activity" that are informed by two fundamental strategic orientations found within each adult day service: "Life as Activity" and "Health and Rehabilitation" (See Figure 5). "Life as Activity" includes those activity realms central to daily social life: coming and going, walking and exploring, daily life activities, cooking and dining, and being outside. "Health and Rehabilitation" addresses personal care, both toileting and bathing, as well as physical and related health support activities.

The Difficulties of Diversity

Thus there is a diverse range of activities that facilities for adult day services need to accommodate and hopefully maximize. This diversity is compounded by the heterogeneous participant profiles that ADS serve. Table 1 illustrates some measures of this incredible diversity. Given that ADS develop individualized plans of care for their participants, the diversity within each activity listed above should be seen as quite great, serving people from the developmentally disabled young adult to the octogenarian suffering with Alzheimer's.

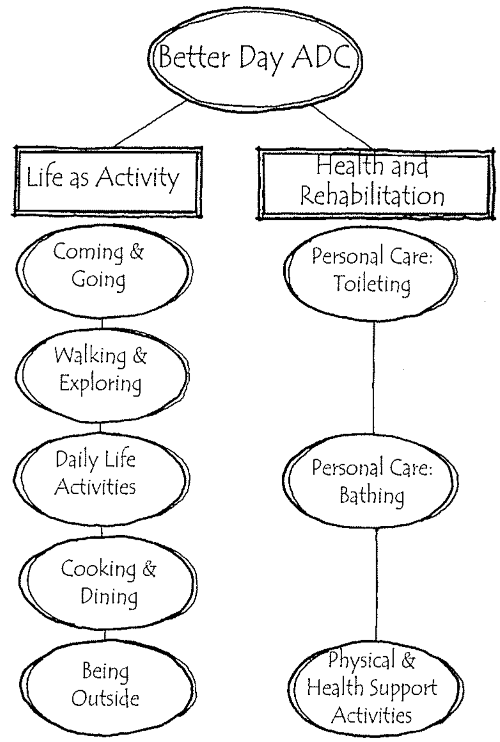
This creates a significant design challenge and requires a critical understanding of the "day in the life" of adult day programs. Unfortunately, the design solutions that are typically found in practice are those that take the "lowest common denominator" approach, commonly referred to as the "multi-purpose room." This solution is to provide the largest, most wide-open space possible and suggesting that solution promotes "flexibility." In the end, those spaces are effective for very little, and often provide an impoverished environment for those for whom the environment is an increasingly important therapeutic resource.

The Church Basement

Diaz Moore suggests the prevailing character of most adult day services centers is that of "The Church Basement."[15] This reference to the historical root of many adult day centers is meant to convey the concept of a large space in which different activities take place and from which there is little, if any, variation in either activity or stimulation or in the degree of visual exposure. This character or "personality" of a place has several negative outcomes associated with it.

First, in regard to sociality, such an environment, being so large and with unfettered visual access, makes every interaction seem public. From previous research, we know that public interactions are those of least therapeutic potential.[16] Rather, the design of social settings should try to encourage interactions of an intimate or personal character, difficult in a "church basement." Secondly, the opportunity for competing stimuli to be present in such a cavernous environment is high, and given the lowered sensory acuity experienced by the elderly and developmentally- disabled, this is counter-therapeutic. Additionally, we know large spaces coercively encourage large group activities (even if the design intention is to be flexible, the experienced reality is typically quite fixed). Just in terms of visual and auditory acuity, groups of larger that 12 people are likely to place individuals beyond to distance of their reasonably expected abilities. This coercively thwarts participation in activity and encourages social withdrawal.

Figure 5. To aid in activity programming, we have identified two central strategic orientations commonly found in adult day and a total of eight realms of activity that can be organized into these two strategic orientations



Such a design also negatively influences participant control as there are no choices provided. Without opportunities to express choice and seek respite, people are likely to suffer what Kaplan refers to as "directed attention fatigue."[17] Given that the population is frail and likely possessing a "progressively lowered stress threshold" anyway, this again illustrates a manner in which such spaces are likely counter-therapeutic.[18] Adding to this is the strong sense of conformity such environments cue. This population suffers a significant level of cognitive impairment and efforts to conform are often quite difficult. To be in an environment without choice and demanding conformity is likely to lead to negative outcomes, such as agitation or withdrawal.

These conditions lead to the following characterization common in many adult day settings:

> There is a large group of older adults—oversized for the given activity — within an ill-defined, open space in which staff provide the most salient cueing for what behaviors are appropriate within a highly structured formal program. Activities are unfortunately coercively rigid due to the public nature of the setting and the scarcity of resources (financial, personnel, environmental) found in the place.[19]

Problematic in this description is the uniform spatial organization, the scant environmental resources provided and the poor composition of these together which fails to cue expected behavior.

Table 1.

Demographic examples of the diversity in participant profiles*

Age (low-high/average)	18-109 / 72
Percent experiencing dementia	52%
Percent considered frail	41%
Percent Developmentally challenged	24%
Percent Physically challenged	23 %
Percent with HIV	9%
Average number of ADL's that Require assistance	over 2

* = data reported by Cox, 2003

What Adult Day Services Should Be

From a design perspective, adult day service facilities should promote if not maximize the therapeutic intentions of the adult day services program. As we see it, the core problem can be summed up succinctly: Adult Day Services is still an emerging place type. The Adult Day Service Center remains an emerging place type because the concept is still new and unfamiliar — architecturally, functionally, organizationally, and experientially — relative to other place types. This unfamiliarity breeds design responses that are ill-informed and thus hesitant in nature. Our task through this research is to highlight not only what should be done in terms of design, but unveil the complexities of adult day services as places.

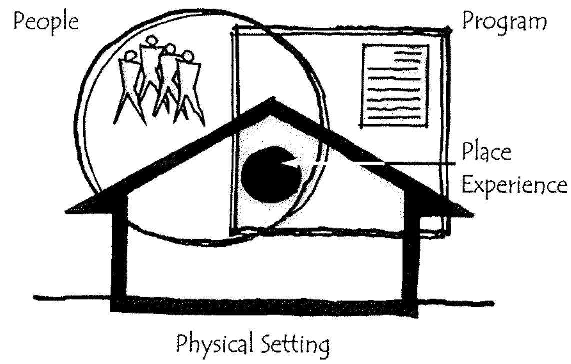
The Concept of Place

Through our research and consulting in the area of adult day service design, we uncovered that there is a lack of systemic thinking in regard to creating adult day services as places. We believe the collective focus must go beyond thinking of the building, organizational mission and staffing structure independently, to a focus on the living, breathing place that emerges from the system of interactions between people and physical settings. Place is one of the central, integrating ideas of this research. We define a place in terms of three components – People, Program, and Physical Setting – organized in a coherent fashion. At the intersection of these three components is Place Experience (Figure 6). Thinking in terms of places —and the experiences, good or bad, which they engender — is the best way we know to improve upon lessons learned from the past, and to develop innovative solutions. Solutions that integrate the architectural, programmatic, organizational, and experiential to create supportive settings that successfully meet the needs of the elderly and people with dementia.

Our belief is that when the spatial organization of the setting as well as its "personality" are consistent with and facilitate the organization's program of activities—and the desired qualities of those activities—the setting will fit more tightly with the programmatic intentions and be more likely to facilitate the anticipated therapeutic benefits. Earlier, we presented eight "Realms of Activity" central to most adult day service programming. While not an all-inclusive set of activities that may occur in adult day services, addressing these eight realms efficaciously in terms of both programming and design would go a long way toward foster better quality of life experiences for participants. These activity types need to be understood as involving a system of activities, involving various people having various needs to various degrees and at various times, but orchestrated to achieve certain purposes (or meet certain needs). Thus a first step in architectural programming is to identify the likely needs of all those involved (participants, family, staff, and organization) and clearly articulate the intentions associated with the activity. The second step is to identify the full system of activities that constitute the Realm of Activity and translate that system into a conceptual organization of settings that would enable and hopefully maximize the sequencing of those activities. The third step examines that organization and attempts to define the spatial requirements desired to maximize the intentions of each activity.

Following this method, we have developed a set of normative patterns in our efforts to support the therapeutic enhancement of adult day services, particularly for those serving the cognitively impaired.[20] Figure 7 is a "concept map" that depicts the relationships between the two Strategic Orientations, the eight Realms of Activity, and 22 patterns that we believe are central to the provision of care in a dementia-capable adult day facility. These 22 patterns reflect our best understanding of those activity-setting combinations most relevant to adult day services and with the greatest potential for therapeutic enhancement.

Figure 6. Our Model of Place



Recognize that not every pattern may be appropriate for every adult day care facility. Placemaking is a site/context specific activity demanding negotiation with local factors. Thus we would like to underscore our assertion that the patterns in this chapter are not the final word, but rather are meant to be a useful beginning repertoire, one that should evolve over time and with experience.

Given the limitations of space, only one pattern will be presented in its entirety and two other key patterns will be summarized. We present *Toilets Distributed Throughout* in its entirety because of our sense that it is the critical thought process shaping these patterns that is as meaningful to creative, quality design as the recommendations themselves. The other two patterns that are summarized are *Socially Supportive Dining and Zone of Transition.*

Patterns for Placemaking

Toilets Distributed Throughout

Toileting is an essential part of everyday life with significant implications on quality of life. This is an activity we engage in independently once trained and expect to do independently throughout life. For many participants in adult day services, this is, of course, not the case. In fact, family caregivers report incontinence as one of the most burdensome effects associated with Alzheimer's Disease and a likely rationale for seeking adult day services.[21] Caregiving practices need to focus on providing support as should the physical environment, but the need to emphasize independence as much as possible in this realm of activity cannot be overlooked.

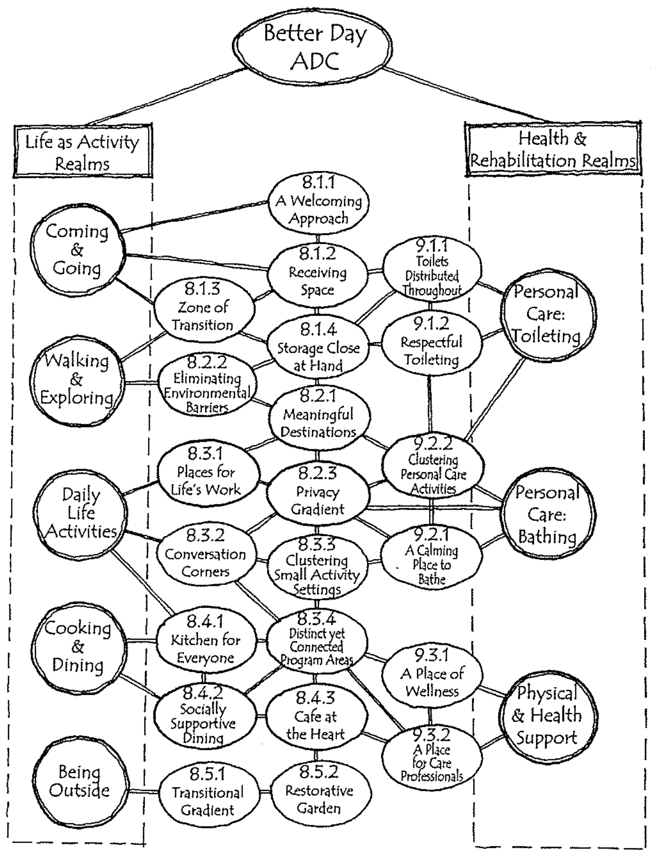


Figure 7. A concept map relating the eight realms of activity to the 22 design patterns developed

There are several essential dimensions to the toileting experience all stemming from the concept of promoting independence. First, a sense of autonomy is enhanced if one perceives a sense of control which may be enhanced through privacy regulation. Independence is also enhanced through the support of functional abilities. Given the heterogeneity of needs found in adult day services suggests the need to provide a range of toilet room types (independent, fully accessible; one-person assist; two-person assist). This will facilitate staff and participant abilities to find the environment most congruent to the presenting needs. Finally, because personal care is such an intimate activity, fear and anxiety can easily be aroused. The need to develop a sense of safety and security associated with the activity is essential to lessen the likelihood of these manifestations.

Problem Statement

Toileting is an important activity in relation to perceived independence. As such, every effort should be made to support participant independence. With regard to location strategy, the toilets that are close and easily recognized are those most likely to be used; those that are centralized or hidden demand greater physical and/or cognitive competence in order to be utilized successfully.

Spatial Requirements

Locomotion to the toilet is heavily impacted by way finding abilities and the presence of environmental barriers. In response to these issues, the spatial placement of toilets is critical to how well they may foster sustained levels of independence in toileting. Providing toilet rooms that are visible and a short distance from activity areas and are along clear circulation paths may effect independent use, perhaps requiring only verbal prompts from staff for some participants who otherwise may need assistance in another environment.

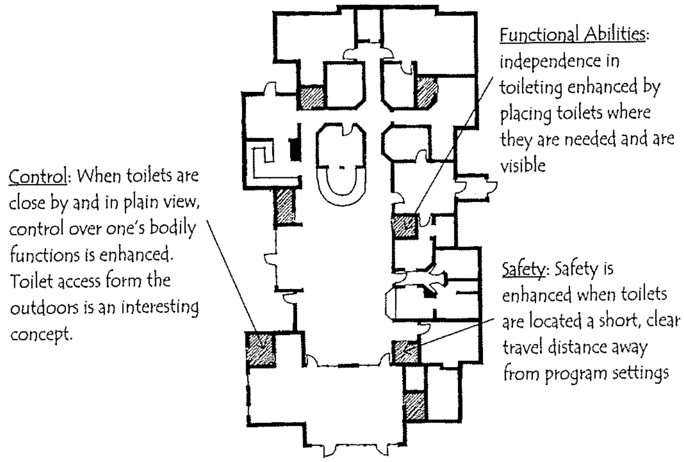


Figure 8. Diagram of "Toilets Distributed Throughout"

Design Response

Toilets Distributed Throughout (Figure 8) conveys the need to provide an appropriate number of private, home-like toilet rooms that are distributed throughout the facility, proximate to activity areas and/or circulation paths, and that serve a range of assistance needs (e.g., independent, accessible; one-person assist toilets; and two-person assist toilets). Toilet rooms should be visible from the program spaces, and toilet-related sounds and smells controlled without impeding visual access or privacy. In accord with 2002 NADSA guidelines for serving those with cognitive impairments, Accessible, Respectful Toileting should, at minimum, provide a ratio of at least one toilet for every six participants, and locate toilet rooms within 40 feet of program spaces.[22]

The remaining two patterns will only be presented in regard to the problem statement and the proposed design response. We hope you will refer to *Designing a Better Day*, soon to be published by Johns Hopkins University Press for further information such as space requirements and other useful recommendations.

Socially Supportive Dining

Problem Statement

Dining is a crucial element of any adult day service program. It is a multi-faceted activity with psychosocial, cognitive, and physical dimensions. Dining is also the most staff intensive period of the day. This highly complex and critically important experience is too often standardized in adult day settings and conducted in one large area. Such an approach hinders the ability of the organization to target and provide appropriate levels of care to individual participants.

Design Response

Socially Supportive Dining (Figure 9) suggests that both the physical and organizational design respond to the range in eating abilities present in adult day settings serving those with dementia. Dining should occur in a space that is visually and spatially distinct from other program settings. Multiple settings suitable for dining should be provided as necessary to accommodate the daily census. No single dining setting should serve more than 16 participants, as unpredictable social and sensory stimulation is likely to result. Participants should be allowed to choose where and with whom they sit during meals and snacks. Dining tables (seating for four to six people) should be reserved for meals and snacks, and rarely, if ever, used for other programmed activities. Typical residential or restaurant-style tableware (no paper plates, plastic silverware or plastic trays) should be used. Mealtime assistance, whether individual or provided to the group at a table, should be natural, dignified and unobtrusive.

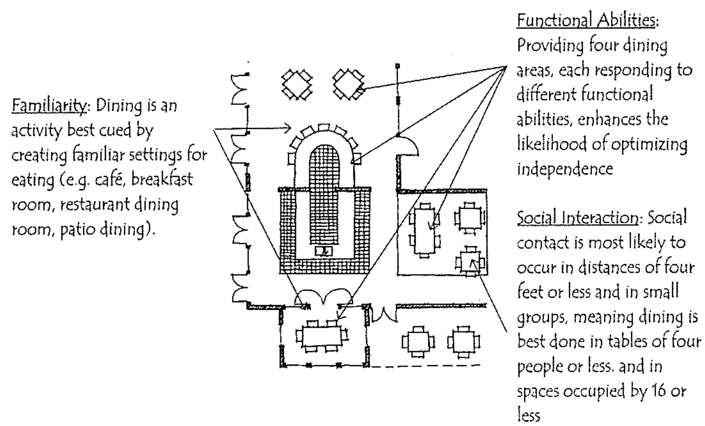


Figure 9. Diagram of "Socially Supportive Dining"

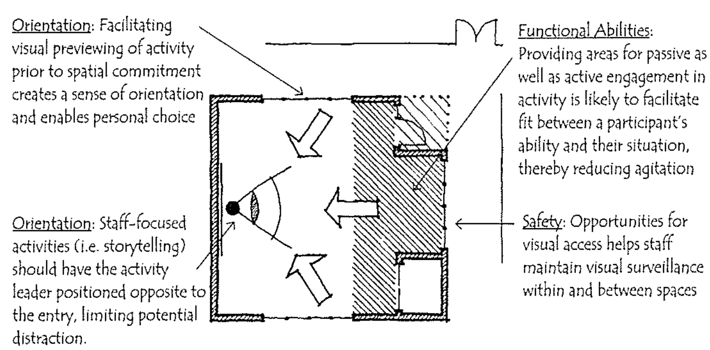


Figure 10. Diagram of "Zone of Transition"

Zone of Transition

Problem Statement

Participants are easily agitated during the coming and going transitions found in adult day service settings. Many cues (i.e., donning coats inside the program space in preparation for departure, and having the exit door readily in view of participants) may contribute to agitation. Easing transition by affording participants time and space to incrementally adapt to different areas and reducing cues that may trigger adverse activity (such as elopement) are essential.

Design Response

Zone of Transition (Figure 10) refers to creating a spatial "buffer" area between entry spaces and program spaces as well as an experiential "buffer" that signals the transition from home to day care program. The entry and reception area should be separate from the primary program space and not visually accessible from it. Security measures that are located within that transition zone should not give an institutional impression but be discreet in appearance and tone. The Zone of Transition should, at minimum, be facilitated by these three features: (1) a buffered entry; (2) opportunities for visually "previewing" program areas, and (3) be supported programmatically by conducting activities some distance and oriented away from points of entry and exit.

Evaluation: An Ending...and a Beginning

As may be seen above, each design pattern is actually a set of bundled design ideas crafted to forward a particular aspect of a particular realm of activity with specific design intentions driving the proposals. Together, these form "bundled hypotheses" between design action and anticipated outcomes. These hypotheses are more clearly expressed in the 164 item evaluation assessment called the Adult Day Center Environmental Design Assessment (ADC EA). The ADC EA is organized in relation to a common set of Attributes of Place Experience described in the book. For each Attribute, the ADC EA lists a series of statements that describe certain elements, qualities, characteristics or attributes of the environment. Each statement reflects an aspect of an adult day service setting that we believe contribute to positive place experience, and which we consider necessary to providing quality dementia-capable adult day care. Yet what is important is the hypothetical nature. While the recommendations are "strong inferences" based upon a solid combination of empirical research and theoretical linkages, they remain hypotheses to be either validated or falsified. We would hope to see these ideas tried and evaluated, so that we may continuously improve the state of the environment for those in society who need a quality environment the most. For we believe that quality of life is enhanced by quality places and that "the right to a decent environment is an inalienable right and requires no empirical justification."[23]

Notes

1. See National Center for Health Statistics, *Health, United States, 2004* (Hyattsville, Md.: Department of Health and Human Services, 2004).
2. See Bruce Vladeck, *Unloving Care: The Nursing Home Tragedy* (New York, N.Y.: Basic Books, 1980).
3. See Erving Goffman, *Asylums* (Garden City, N.Y.: Anchor Press, 1961) and Jaber Gubrium, *Living and Dying at Murray Manor* (New York, N.Y.: St. Martin's Press, 1975).
4. See William Brummett, *The Essence of Home: Design Solutions for Assisted Living Housing (*New York, N.Y.: Van Nostrand Reinhold, 1997); Victor Regnier, *Assisted Living Housing for the Elderly: Design Innovations from the United States and Europe (*New York, N.Y.: Wiley, 1994); and Victor Regnier, *Design for Assisted Living: Guidelines for Housing the Physically and Mentally Frail* (New York, N.Y.: Wiley, 2002).
5. See National Adult Day Services Association, *Standards and Guidelines for Adult Day Services (*Washington, D.C.: National Adult Day Services Association, 2002).
6. *Ibid.*
7. Shirley Travis, et. al., "Adult Day Services in a Frontier State," in *Nursing Economics 19* (2001): 62–67.
8. Julia Bradsher, Carol Estes, and Margaret Stuart, "Adult Day Care: A Fragmented System of Policy and Funding Streams," in *Journal of Aging & Social Policy 7* (1995): 17–38.
9. See Robert Kane and Rosalie Kane, *Long-term Care: Principles, Programs, and Policies (*New York, N.Y.: Springer, 1987).
10. Bradsher, "Adult Day Care": 20.
11. Stephen Golant, "The Promise of Assisted Living as a Shelter and Care Alternative for Frail American Elders: A Cautionary Essay," in B. Schwarz and R. Brent, eds., *Aging, Autonomy, and Architecture: Advances in Assisted Living* (Baltimore, Md.: The John Hopkins University Press, 1999), 32–59.
12. See Nancy Cox, "A National Study of Adult Day Services," presented at the First Annual Conference of the National Adult Day Services Association, Miami Beach, Fla., 2003.
13. *Ibid.*
14. See Keith Diaz Moore, Lyn Dally Geboy, and Gerald Weisman, *Designing a Better Day: Planning and Design Guidelines for Adult and Dementia Day Centers* (Baltimore, Md.: The Johns Hopkins University Press, forthcoming).
15. See Keith Diaz Moore, *The Hidden Program of Adult Day Care for the Cognitively-impaired: A Comparative Case Study into the Negotiation of Place (*Ann Arbor, Mich.: UMI, 2000).
16. See David Unruh, *Invisible Lives: Social Worlds of the Aged, (*Beverly Hills, Calif.: Sage, 1983).
17. Stephen Kaplan, "The Restorative Benefits of Nature: Towards an Integrative Framework," in *Journal of Environmental Psychology 15* (1995): 169–182.
18. Geri Hall and Kathleen Buckwalter, "Progressively Lowered Stress Threshold: A Conceptual Model for Care of Adults with Alzheimer's Disease," *Archives of Psychiatric Nursing 1 (*1987): 399–405.
19. Keith Diaz Moore, *The Hidden Program*, 313.
20. See Christopher Alexander, *A Pattern Language* (Oxford: Oxford University Press, 1977).
21. See Jon Pynoos and C. Stacey, "Specialized Facilities for Senile Dementia Patients" in M. Gilhooly, S. Zarit, and J. Birren, eds., *The Dementias: Policy and Management* (Englewood Cliffs, N.J.: Prentice-Hall, 1986).
22. See National Adult Day Services Association, *Standards and Guidelines.*
23. M. Powell Lawton, *Environment and Aging,* Albany, NY: Center for the Study of Aging, 1986.

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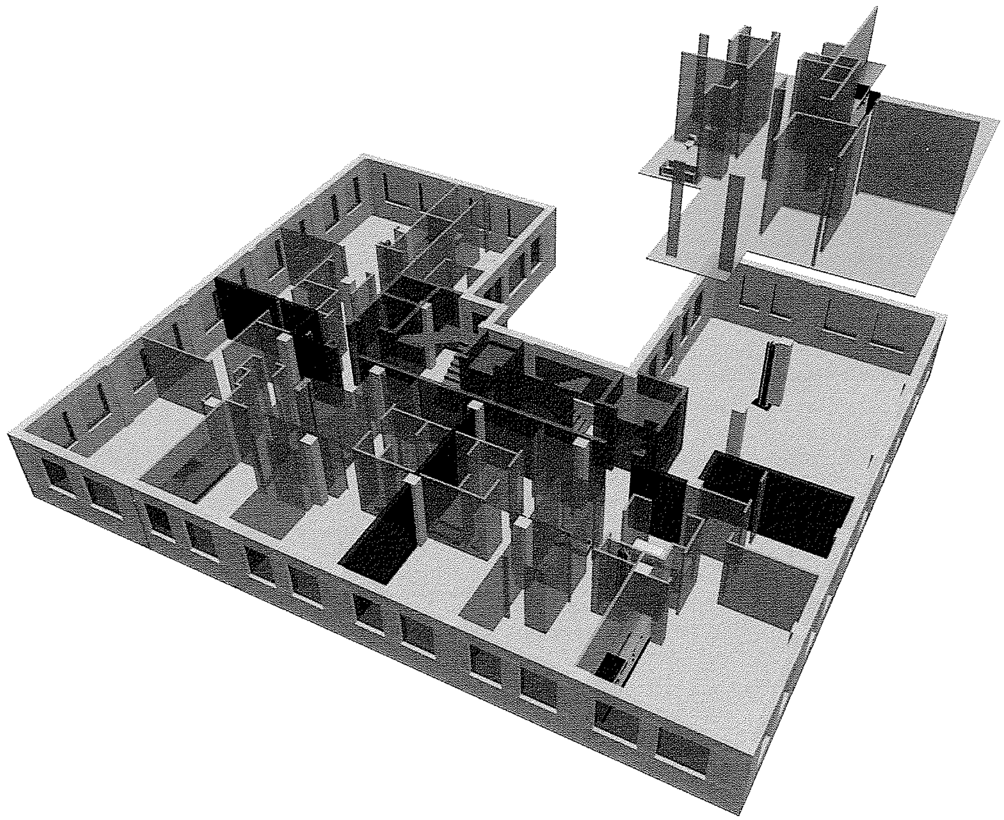


An Open Building Strategy for Converting Obsolete Office Buildings to Housing

Stephen Kendall PhD

Director, Building Futures Institute
Ball State University

Adaptable, multi-family housing—row house, walk-up and elevator types—must sooner or later become an attractive alternative in the United States to detached housing "sprawl". To help, the housing finance industry must offer financing instruments focused on the continuous process of "stock-maintenance and upgrading". Further, the building design, construction and logistics systems must implement practices and processes to match this perspective. These changes are important in respect to two kinds of constituencies at work in multi-family housing. One is the market of large investors, developers and public agencies, its own forces and decision-making processes to contend with. This market seeks uniformity and resists change. The other is the consumer market, having its own dynamics and forces. This market seeks variety and capacity for "fine-grained" change suiting individual households. These two markets are related, like highways [public goods] and the vehicles running on them [private goods], and both must act to make healthy housing processes and environments. But they must be distinguished (disentangled) to optimize the effectiveness of each.

Given these premises, a study was undertaken between 2001 and 2004 on the subject of the conversion of obsolete office buildings to residential uses. The study was undertaken from the perspective of the development, design and construction fields. The process we report on will result in greater physical and legal autonomy to the individual unit in multi-unit buildings, in the conversion of existing buildings (e.g. office buildings) to housing. Many of the lessons can apply in new construction. What is reported on is suited to the problems "one-unit-at-a-time gut-rehab" and long-term sustainability—that is, balancing supply and demand over the long term with minimized disruption, waste and conflict.

For rehabilitation processes to become aligned with the two constituencies mentioned above, technical and organizational rigidity and entanglement, so characteristic of multi-unit buildings, need to be overcome. It is well known that condominium and other multiple occupancy residential projects are more prone to legal conflict, difficult remodeling, renovation and upgrade processes, than any other occupancy type. This can be largely attributed to physical "entanglement" of the "common elements", the "limited common elements" and the "individual elements"—that is, their physical and thus decision-making "integration". Technical, economic and spatial decisions about one unit are far too entwined with decisions about other units, bringing about conflict and overlapping spatial and technical claims during a buildings' useful life. It is therefore important to design and rehabilitate multi-unit buildings to avoid such conflict, thus reducing dependencies among and between stakeholders, including occupants, and the parts of the building they control or use. The point is to make a clear distinction between the "shared" parts and the "individual" parts.[1] This will go a long way toward making living in multi-unit buildings more attractive to households who now enjoy the relative freedom of living in detached houses in typical suburban developments.

The housing rehabilitation approach reported on in this paper—given the name "open building" in international theory and practice[1]—can be one part of the effort to make urban living attractive and affordable to a variety of households—thus it can serve as part of the bundle of strategies serving as an antidote to sprawl.[2]

This approach can also be a tool for achieving—over time in a given building—the goal of income mixing and community stability. That is, instead of building (or converting) housing according to initial household income (assuming fixed incomes subsequently), an open building approach enables a more dynamic balance between physical assets and changing household income over time. It helps us avoid the trap of real estate development and building practices based on (income) class. It also is a tool in adjusting our practices from a "scrap and build" approach to a "sustainable stock" approach.

In our study, we examined related topics including legal issues, labor, product manufacturing, product bundling, diffusion of innovation in the construction sector, the public policy environment for urban regeneration, and issues related to a new hybrid business that may help to solve some of the widely experienced problems in the construction processes in conversion. We examined legal issues surrounding conversion, and speculated about the relevance of a financing strategy used in the Netherlands and its possible use in the US. We also sketched out a business plan for a "fit-out" company. We also speculated on the problems of the diffusion of innovation in the construction industry, and placed the proposal in the context of "systems innovation" and current trends in "product bundling". Only some of this work is reported here.

BUILDING CONVERSION

"Across the United States, vacant office buildings, warehouses, department stores and hotels are getting a second chance at life as a new housing stock. By nature, adaptive reuse is time consuming, complex and costly. However, that has not stopped an increasing number of developers from pursuing housing conversion projects."[3]

"Office vacancy rates have been rising across the country. Older Class B and Class C buildings in most markets have been hit particularly hard, because so much new or nearly new Class A pace is available for lease or sublease. At the same time, many cities are struggling with significant housing shortages, because residential construction and renovation have not kept up with demand, and because many cities have started growing again after years of stagnation or decline."[4]

Conversion—or adaptive reuse—is one of a number of processes available to developers who seek profit from investing in and improving existing properties. Housing rehabilitation more generally is a normal if under-studied economic activity of significant magnitude in the United States.[5] Conversion is just one of many rehabilitation strategies in which a previous use is changed to a new use suited to changed market conditions. Normally, this process involves real estate assets of some historic value or at least of salvageable value, where the alternative of "scrap and rebuild" is not possible, is prohibited or is more expensive.

Complete conversion of an existing building from one use to another, as noted above, is widespread in the United States and has been increasing. If an American Institute of Architects projection is accurate, in two decades 75 percent of architects commissions will involve conversion,adaptive reuse and rehabilitation of existing structures, and only 25 percent will be "new" construction.[6] With increased incidence of conversion and the need to address the structure of regulations and incentives available to spur and guide such work, a number of national organizations have produced useful guidelines. One such guideline is the recently published NARRP guidelines for building rehabilitation.[7] It offers an important tool that addresses the wide range of magnitudes of conversion or rehabilitation work.

THE CONVENTIONAL PROCESS

The initial rationale for development—new construction of conversion—is based on a preliminary building analysis, projected market demand, financing availability, and regulatory constraints. A "pro-forma" giving unit mix and layouts is made. Building design and cost estimating follow the packaging of the financing and public approvals, and construction follows.This sequence can present difficulties because the time between decision to convert and actual lease-up or sale of units can take several years, during which time the market, interest rates,investments, prices on construction labor costs, and other factors such as regulatory constraints may and usually do change. Since the conventional process assumes a complete"program" of decisions about unit mix, layouts and equipment, it does not easily lend itself to the kind of "agile" decision process needed; decision processes that are well understood in office and retail developments. This makes the entire process overly rigid and prone to waste, conflict, and excess costs. It also offers no place in decisions for individual occupants, thus keeping this process outside the consumer market, where it should be.

This process may work well in a stable context, but in dynamic markets such tightly sequenced decisions are ripe for difficulty. Where social and technical dynamics are fast paced, it is not unusual in a conversion process for the unit mix and unit layouts to change several times before construction begins, requiring extra work for the design team, estimators, and developer. These consultants are not always compensated, nor are they well equipped to manage these dynamics. Knowing that these changes are inevitable, only schematic work is done requiring many "rules of thumb" for estimating purposes and excessive dependence on guesswork. Delaying the building's technical decisions until the last minute produces conflict, waste, mistakes and increased quality control problems. These problems arise because the design and decision processes assume the building as an integrated whole, in which decisions are highly interdependent, producing an overly rigid state of affairs in which the resulting decision process is unable to account for change on the various decision levels involved.

AN OPEN BUILDING APPROACH

These problems pose new challenges and opportunities for architectural and engineering knowledge, as well as business practices, construction management, the building trades, supply channel logistics, and information technology. Based on our studies, we believe there are two key questions these fields now have to address:

1) "How can we adopt the most advanced processes of design, manufacturing, and construction in the conversion and upgrading of existing buildings - and the construction of new buildings -prepared for inevitable change?"

2) "How can we organize these processes with full recognition of the individual household—the basic social and economic unit of society—thus balancing the requirements and preferences at the community level with those of individual households in control of "everything behind their front door?"

Our research addressed these questions by means of a study of the conversion of an 18-story office building in Detroit into residential units. The conversion is actually being undertaken using conventional means, thereby affording us a useful basis for comparison of the alternative strategy described in this report. Our near-term goal is to accurately describe how this process works, in sufficient detail that the "open building" process makes sense to professionals in the business of bringing residential projects to market.

The study focuses on an innovative strategy, including a new way of outfitting residential units by means of fit-out packages. A fit-out package allows the rapid installation of partitions, heating and air conditioning, kitchen and bath equipment, and finishes with all the piping, wiring, and ductwork related to this equipment. Installation is done per unit according to the floor plan selected for that specific unit.

The fit-out approach is of interest for two reasons. First, it offers an individualized approach to large residential conversion, rehabilitation or new projects. Second, it is arguably close to being economically competitive compared to existing strategies of outfitting dwelling units, while offering much needed decision flexibility and quality control. We hope to show that it, therefore, constitutes a breakthrough combining improved decision flexibility, work structuring, materials flow reliability, and consumer orientation with more efficient production.

THE PROBLEM OF DIFFERENCES OF SUPPLY AND DEMAND

From a residential developer's perspective, one of the most difficult problems is matching supply with demand, both initially and over the life of the investment. Given the complexity and high risk of residential development and conversion of older buildings to housing in particular, and given the often lengthy development process, developers typically seek methods that enable decisions to be deferred and options to be kept open as long as possible without leading to increased cost and risk. In respect to developers' efforts to provide residential properties that meet actual (not statistical) demand, it is well known that consumers in the "for-sale" market frequently prefer changes of the standard floor plans normally offered to them. Even if a specific floor plan is preferred from the menu of options, a customer may want to change a door's location to enable the family to move in a favorite piece of furniture. Or, the customer may want to move a wall. Frequently, consumers want to select their bathroom and kitchen layouts, equipment, and finishes.

If competition in the market is strong, developers will have to give in more quickly than when demand is weak. But if they could, developers would not offer any choice, because it will cost them money. It is not clear that the cost of customization can be passed on to the buyer. The contractor's pricing is based on fixed floor plans and specifications. Any change will be disruptive to their estimating, delivery, and management processes. Contractors also know that developers frequently demand floor plan changes, because they fear that otherwise some units will not be sold or rented. This puts them at an advantage over the developer to negotiate prices. But it is also true that it is difficult for the contractor to manage such changes and to determine their exact costs. Prices will be established—usually increased—accordingly, to cover uncertainties. This situation puts developers, homebuyers and builders on a collision course. The tensions and conflict that are so familiar come from the "disconnect" between demand for customized units, the desire for decision deferment, and the ability to deliver. The second source of tension comes years later when the units and the building as a whole must be adapted to meet changed homeowner preferences, standards and codes, and the building is found to be so technically entangled, that sought-after adjustments cause excessive difficulties and costs.

Figure 1. The Kales building, downtown Detroit

RECONCILIATION OF CONFLICT

The Open Building approach uses a design method—"capacity analysis"—and a new logistics strategy using fit-out kits. The developer asks for bids only for a "serviced shell" or "base building". The developer gets a finished building complete with windows and exterior finishes, public circulation spaces and all of the "shell" mechanical systems and services. The base building establishes the kind of lifestyle and quality of services that the buyer or renter needs to know before deciding if the location is interesting. But the inside of the units will be empty and ready to be filled in. Floors are smooth. Ceilings and base building walls are finished and painted. At one or two fixed places in each unit there is access to electricity, water, gas, and sewage for the fit-out "kit" to connect to, for further distribution in the dwelling unit.

Constructing this base building should not present difficulties to the builder. The builder is, infact, freed of the part of the construction process (the unit fit-out) that usually constitutes the greatest risk and takes most of the overhead for on-site management and coordination of subcontractors. It is well known that money is easily lost on finishing the interiors of units, while it is gained in constructing the base building. The builder, in short, can now do more with lower overhead.

For his part, the developer knows precisely what to expect from the builder in terms of product and timing. For the fit-out "kit", he contracts a qualified "fit-out" special-purpose company, and is now in a position to offer the home buyer exactly what they want and can structure prices accordingly. In the case of a rental development, the developer can defer decisions about both the size of units and each unit's layout and level of finish until the last minute, contracting the"fit-out" company to deliver what the developer believes will attract leases.

This approach liberates all parties involved: the buyer, the project developer, and the contractor. The approach is a technical innovation, but has very important commercial implications, putting the developer and the builder in a mode of operation that offers superior service to the buyer in a way that can be well controlled financially. This gives a decidedly competitive advantage over those operating in the traditional mode.

A CASE STUDY: THE KALES BUILDING

In 1990, Mansur Residential Development (based in Indianapolis, Indiana) began assembling the financing to acquire and convert the historic 18 story "Kales" building in downtown Detroit. The financing was originally, and remains, a mix of state and national historic tax credits and bank loans. Early in this process, Mansur conducted a market analysis to determine a unit count, mix and layouts, as well as rents. An architect began to design the floor plans for the conversion. Cost estimates were made based on schematic architectural and engineering designs. Difficulties were encountered in the financing scheme, and other conditions in the market changed, such as interest rates and competition in the local market. These uncontrollable circumstances forced the marketing plan for the building to change. The architect completely revised the number of units, the unit mix, and floor plans, with the normal consequences to the mechanical, electrical and plumbing designs and cost estimates. Initially, five units were planned for each floor; later this was increased to seven, and later reduced to six. Each floor was identical. At a certain point, a decision was made to "freeze" the design, to enable construction bids to be obtained and construction undertaken. Construction was expected to take 12 months.

With the opportunity to conduct a study of an open building approach to conversion, parallel to the actual conversion of the Kales project, we set out a number of objectives:

1. *Offer methods providing the developer with decision flexibility in meeting current and future markets.*
2. *Enable the developer to defer decisions about unit mix and layouts without risk.*
3. *Address the extremely limited space on the site for logistics of construction.*
4. *Enable maximum use of off-site "controlled environment" facilities to prepare ready-to-install "interior fit-out kits".*
5. *Enable subsequent adjustments to the building on a one-unit-at-a-time basis, including conversion to condominium units.*

CAPACITY ANALYSIST

The first step in converting an existing building using an open building strategy involves a design process in which a typical floor plate is analyzed to determine an optimum variety of unit sizes. We applied this method to the Kales Building with results shown below. A series of design studies were made in which vertical MEP "stacks" (mechanical, electrical and ventilation risers)were positioned, and the capacity of the resulting "served" space was evaluated. The purpose was to investigate a range of unit sizes and layouts that could be laid out. This process was repeated several times, each time adjusting the constraints (principally the MEP stack) until an "optimum" number of layouts were demonstrated.

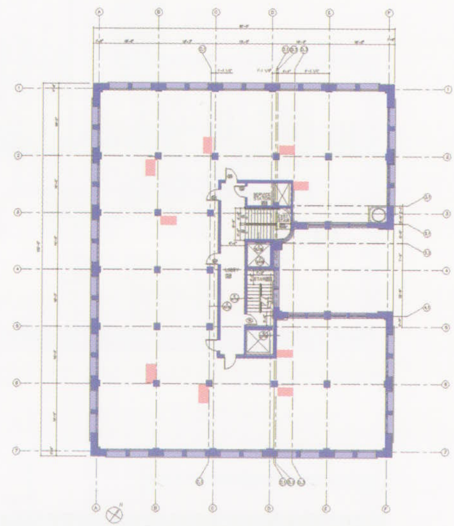


Figure 2. A typical floor showing the new plumbing cores and the existing building

Figure 3. 3-D view of one floor, with the structural columns and MEP shafts, public circulation,elevators and fire stairs

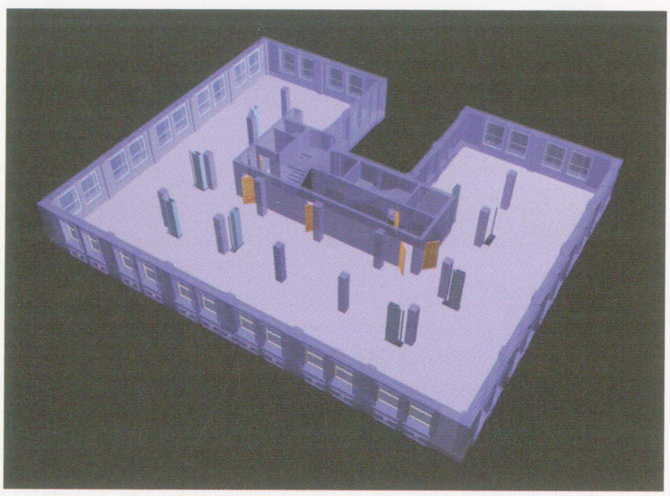


Figure 2 is a typical floor of the building. Its structure and envelope—protected by historic guidelines—and the building's elevators, fire stairs, central MEP shaft, and public corridors, are in blue. They have not changed. The "final" positions of the new vertical MEP shafts (shown in pink) are indicated. We decided to retain as much of the existing building as possible. The existing vertical circulation, main MEP shafts, and public corridors are retained.

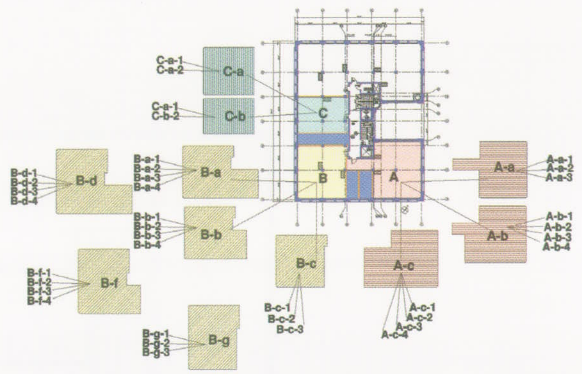


Figure 4. Capacity analysis diagram of a typical floor

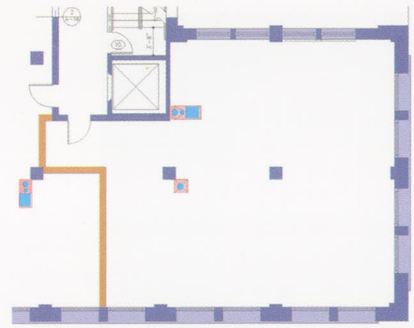


Figure 6. Unit A-b empty, ready for fit-out installation

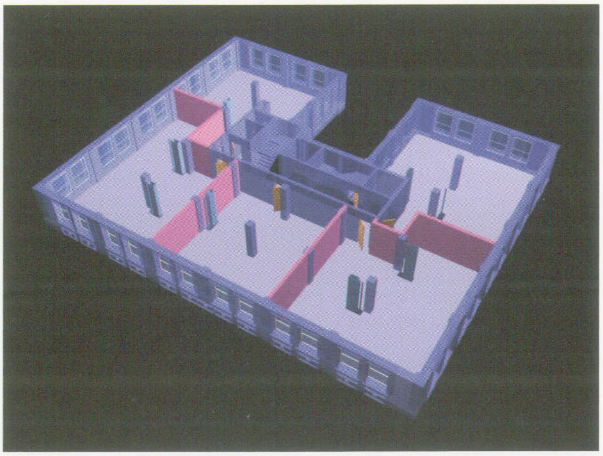


Figure 5. Demising walls based on a specific decision about unit sizes on this floor

Figure 3 shows the full capacity of a given floor plate in the building. Given fixed vertical MEP stacks, a variety of dwelling unit sizes are possible. A "margin" between units A and B and B and C allows their respective sizes to vary. This diagram shows the many unit size variants possible on any floor. Each unit (e.g. A-b) can accommodate a variety of floor plans. This enables the developer, in the case of a for-sale project, to offer a "menu" of choices and to offer occupants the opportunity to make fully customized units exactly meeting individual preferences and budgets. In a rental property, the developer can retain great decision flexibility, and, if the building is to be converted to condominiums later (as the Kales building will be), offer greater customization with less risk.

Figure 6 shows unit A-b empty. The parts in blue are base building elements, including two MEP shafts. The demising wall separating units is yellow.

Figures 7 and 8 are two variants and their horizontal plumbing systems in red. It is important to note that we have avoided any vertical penetrations through the floor, except at the base building MEP stack. The result is that any unit's floor plan is entirely independent of any other, enabling design, pricing, and "kitting" of each unit to be entirely independent.

The above outlines briefly the architectural design process. It uses a design process of initially"fixing" certain constraints (e.g. position of vertical piping chases, assumptions concerning routing of pipes in walls and so forth) and then exploring the capacity of the constrained space to accommodate a variety of reasonable unit sizes and layouts. This process is repeated until agreement is reached that an optimum number of variants are possible, at which point the base building can be constructed with assurance that the developer can maintain decision flexibility.

Once the base building is ready, the developer can decide the preferred unit mix. Because decisions on unit mix and layouts on one floor are independent of those on other floors, the developer can effectively "market" the building unit-by-unit and floor-by-floor. Thus, as the fitout is installed unit-by-unit, the development team can learn what the market demands and can adjust accordingly without risk of disturbing the build-out efficiency.

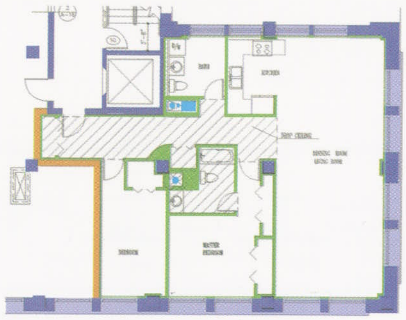


Figure 7. Variant A-b-1

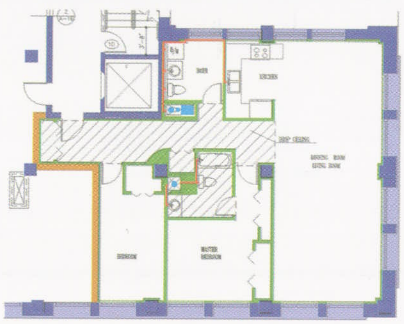


Figure 8. A-b-1 w/ horizontal piping

DESIGN OF CONSTRAINTS FOR CAPACITY ANALYSIST

The evaluation of capacity, described above, is a basic design operation in open building practice. But capacity analysis is impossible without explicit statements of constraints—conditions governing the position and organization of the elements deployed as base building parts and as fit-out parts. Thus the design of such constraints as such is a prerequisite, and deserves special attention. A full capacity analysis requires a number of constraints concerning a range of technical and organizational problems, including the complete description of all MEP(mechanical, electrical and plumbing) systems, their positions, and dimensions in three dimensional space.

Among the many constraints, we have specifically focused on the design of constraints concerning the routing of drainage piping inside a given dwelling unit. All of the MEP systems require careful planning, but we have focused on this because drainage piping is well known to be one of—if not the most difficult—constraints on achieving "flexibility" (variability) of floor plans in residential construction.

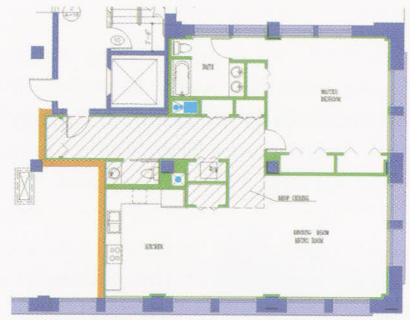


Figure 9. Variant A-b-2

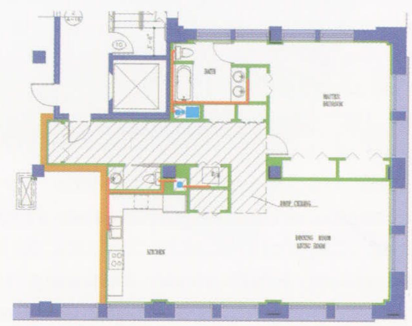


Figure 10. A-b-2 w/ horizontal pipes

The reason for this is that, in order to achieve complete autonomy of dwelling unit decisions, all piping (and cabling, ductwork and other MEP systems) that are part of a unit's layout must not cross into another unit's space, beside, below or above. Therefore, the routing of such drainage lines within the dwelling unit is critical and must be systematically organized. Since the variables are finite and the rules of positioning explicit (based on slope, diameter, and venting rules in building codes), it is possible to notate the constraints that any floor plan must follow to achieve the desired unit autonomy and drainage performance.

First, we adopted the use of floor mounted rear discharge water closets (produced by several major United States plumbing fixture manufactures). We also required that bathtubs and showers be installed at the height needed to enable their traps to be installed above the base building floor. Alternatively, we required use of new "low profile" or "in-line" traps such as manufactured by Hepworth for the European community market.

Second, we defined three horizontal "zones" in fit-out partition walls, in which drainage lines are conventionally positioned: "lower" and "middle" and "high" zones. The "lower" is reserved for drain lines serving WC, shower and bathtub. The "middle" zone is reserved for drain lines serving lavatory, sinks or washing machines. An additional "high" zone nearer the ceiling is needed in some cases for sprinkler lines, and still other zones are needed for horizontal routing of water supply lines, and so forth.

The "lower" zone contains the horizontal drainage lines within 6" of the base building floor. Given the slope of the drain lines as defined by the standard United States plumbing codes (1/4" or 1/8" per linear foot), this defines the distance any of these fixtures may be positioned from the MEP stacks serving that unit. The "middle" zone contains drain lines that start at higher elevations and therefore enable fixtures to be more distant from an MEP stack. Defining these horizontal zones enabled us to make another diagram that serves as a catalogue of routing variations for all horizontal drainage lines—gray and black water—contained in any of the dwelling unit layout variations we studied. Based on the above information, we could make the following diagram.

This diagram displays the variety of layout conditions and the variety of drainage lines and their connectivity rules. In some cases, double walls are required. With these rules, systematic preparation of all piping parts, connections, fasteners, and the partition elements (studs, brackets, holders, and so forth) can be prepared per dwelling unit, supported by dedicated software. These are part of the ready-to-assemble "fit-out kit", prepared off-site at a distribution facility, and contain parts needed to complete a dwelling ready for furniture. Many thousands of discrete parts, in perhaps 30 different product categories, make up a single dwelling unit's fit-out kit. The concept of fit-out kits, similar to "design for supply channel management", is not new, but has not yet been successfully implemented at the level of complexity this project entails.[8] In this sense, their search is proposing an innovation in linking design to production to installation.

Presently, two basic kinds of "bundling" can be observed in construction. One we call "project independent"; the other "project dependent". The first is the result of initiative taken by the producer. The second is the result of initiative taken by the user who orders the "bundle" or "kit". Project dependent bundling or kitting is similar to prefabrication. Elements are assembled off-site for a specific project, to be installed as a whole, when it reaches the construction site it was prepared for. But product bundling or kitting is different, since it concerns the delivery of packages of parts ready to assemble, connoting the idea of boxes of parts small enough for a pick-up truck and to fit through the front door of the house.

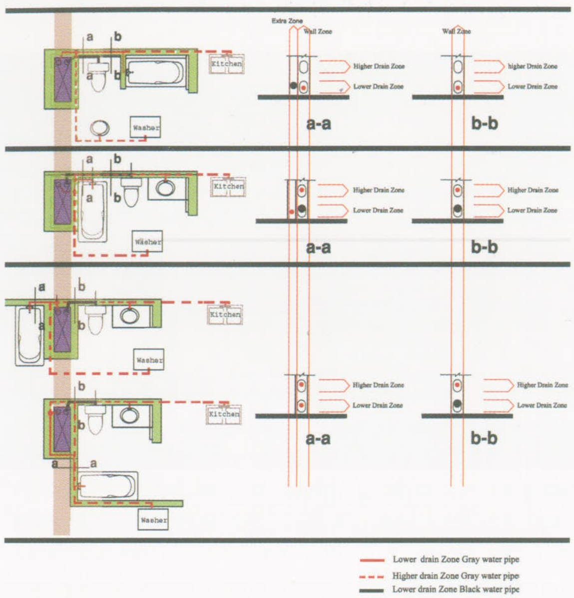


Figure 11: Diagrammatic layout of all variants for the routing of horizontal drainage lines

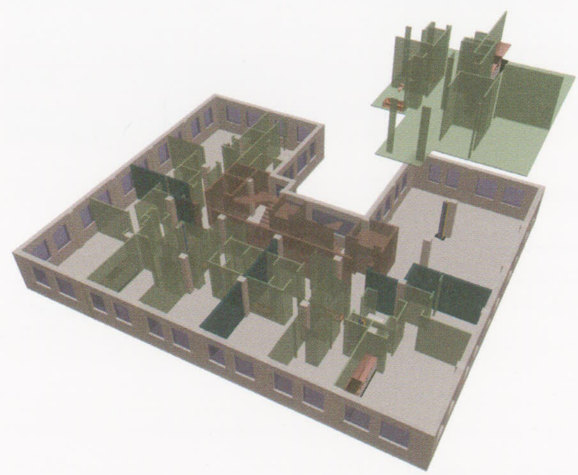


Figure 12. One "product bundle" schematically "lifted out" to show its independence

FIT-OUT CONCEPT FOR THE KALES PROJECT

The kind of kitting we are developing here is project specific. This is an image of the total contents of the fit-out package for one of the units in the Kales building.

Once design specifications for a unit's fit-out is known, the data is transferred to a fabrication center. There, all parts needed for that project are prepared—cut to size, preassembled, or otherwise prepared in the correct number—and delivered to the building. This maybe done in one container, or, in our case, the deliveries are made in several "packages"; following an optimum site installation management schedule. Because of its urban location, the site has limited space for containers to remain in-place during the 3 weeks needed to fit-out a unit. We project a sequence of JIT deliveries to the site from the fabrication facility.

LOGISTICS

The key to this strategy is good logistics. The following diagram, developed in the Netherlands as part of a business strategy for residential fit-out, shows three logistics strategies.

In a conventional supply chain for providing parts for fitting out the empty shell of a building, each subcontractor is responsible for bringing the materials to the job-site and for installing them, in the management process we are familiar with. There is no central information management required, nor would it be easily developed. In a fit-out approach, the flow of information is different. Design, fabrication and installation are integrated. This begins with a clear organization of the parts making up a fit- out package. The diagram above compares the traditional supply and logistics chain (used in the actual conversion process, as well as conventional new construction) with an intermediate and a new logistics strategy. It is the latter strategy we are studying.

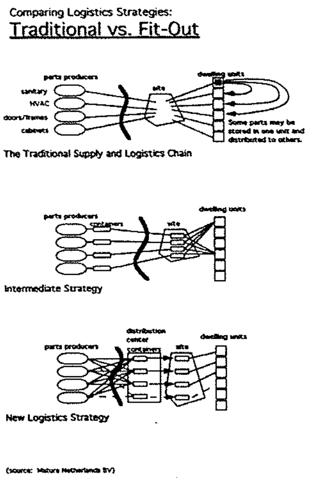
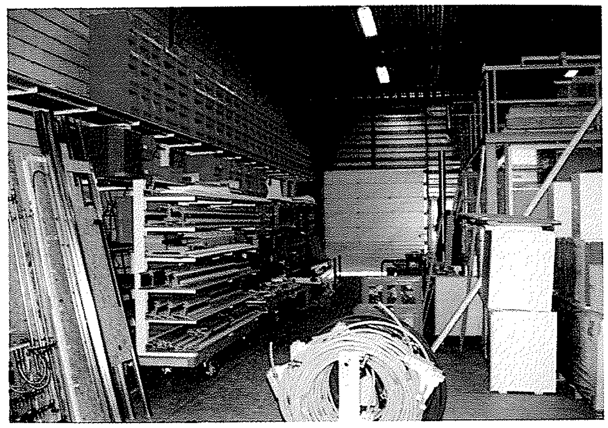


Figure 13. A diagram used to explain the Matura Infill System[9]

Figure 14. View of a fit-out kitting facility



CONCLUSIONS

We have given an indication of the architectural design process needed to prepare an old building for fit-out on a unit-by-unit basis. We have also suggested that this process can be supported by the use of "interior fit-out kits", prepared "ready-to-install" at a central distribution facility set up specifically for such "kitting" processes. A powerful motive in the developments discussed here is to harness the full capacity of industrial production in support of more consumer-oriented and more adaptable housing. Doing so requires that more of the "value-added" in housing processes and products be separated from the part of the house known as "real property". Real estate is deeply political, related to local geotechnical and climatic conditions, to the local sense of place and urban design, as it should be. But an increasingly large part of the "whole house" can be uncoupled from these conditions. This formulation is the open building approach—distinguishing the decisions (and systems) made for the "public" from the decisions (and products) made in respect to the individual occupant. This means the evolution of two distinct markets, mentioned above, and two distinct processes, not in conflict, but in coordination.

Studies on the implementation of the open building approach in the United States indicate that the design knowledge needed to provide architectural services in tune with "capacity analysis" is not difficult to learn. Engineering consultants can design mechanical, electrical and plumbing systems in line with the principles of open building. Contractors understand issues of pricing and logistics, and developers find value in the decision deferment benefits of distinguishing a base building from its more variable fit-out. The one dominating issue now is the organization of skills related to the concept of "kitting" or "product bundling". To implement this approach we need to organize multi-skilled teams of trained installers who do not organize their work along the traditional lines of carpenter, electrician, plumber, sheet rock installer, tile setter, and so on.The building industry—as the automobile industry has learned in the production of the Saturn—now needs assembly teams. Supported by advanced software, the introduction of these design methods and the re-skilling of workers installing fit-out are the next frontiers in the organization of the building process for a more agile, sustainable building stock.

Figure 15. Containers transporting kits

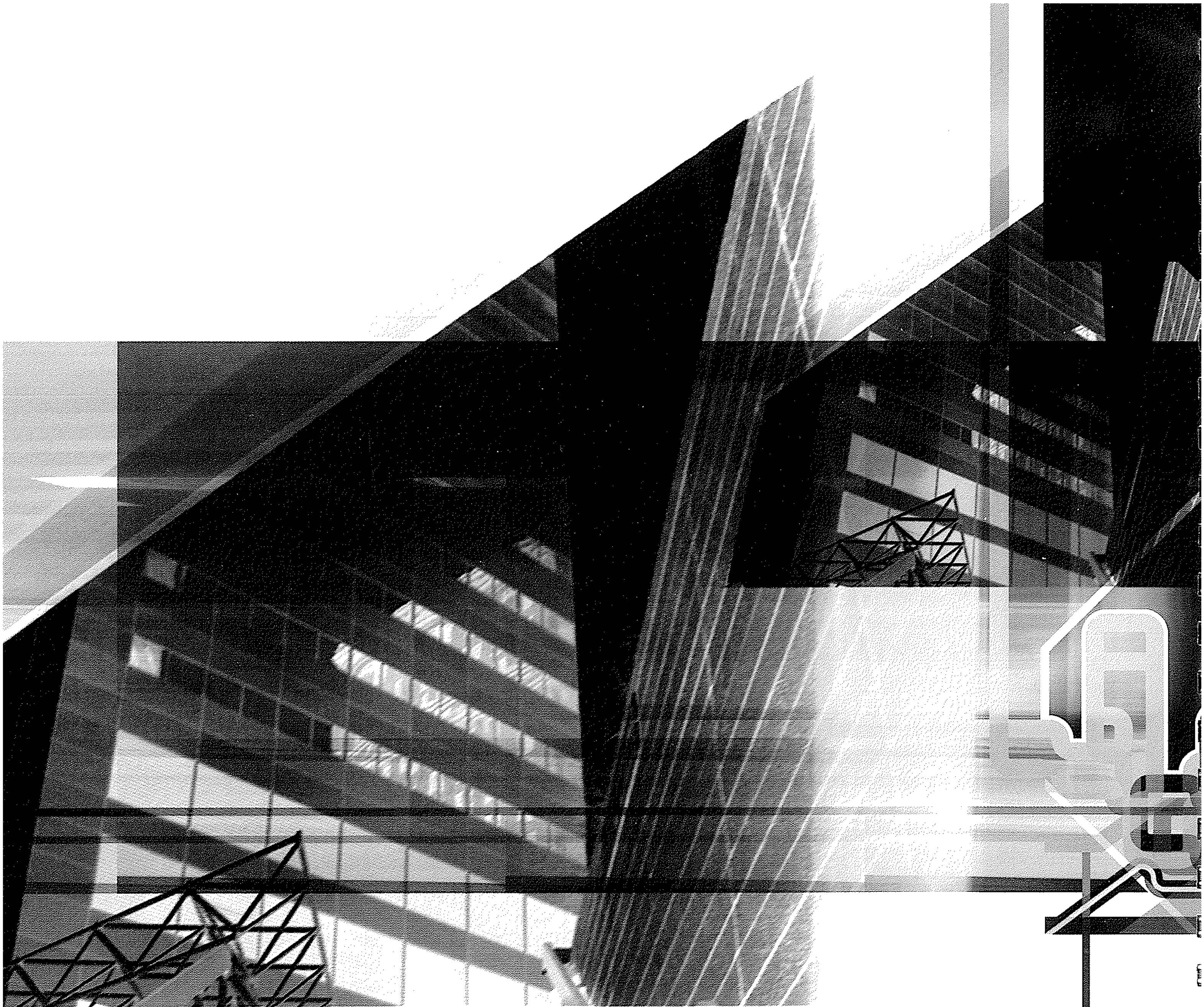
THE PARTICIPANTS IN THIS STUDY

This work has been strengthened by the active participation of several local sources of expertise. First of all, academic colleagues at Ball State University and at Indiana University Purdue University/Purdue School of Technology have added depth and breadth to the study. Second, three companies committed staff to the project, giving us practical knowledge and experience without which the study would have remained academic. Third, a number of students in the College of Architecture and Planning have contributed to the effort, in preparing technical drawings, delineating legal issues involved, in helping to prepare the design, visualization and animation to the study. And finally, a group of students in the MBA program at Ball State have used the project as a case study by producing a business plan for a fit-out company.

This study is the second produced by the Building Futures Institute in cooperation with the International Cooperative Research and Development on Sustainable Urban Management with Conversion of Buildings, led by a research team at the University of Tokyo. Funding for graduate students came from the Matsumura Laboratory in the University of Tokyo Department of Architecture, with support from a grant-in-aid for the Development of Innovative Technology, which in turn is funded by the Ministry of Education, Culture, Sports and Technology of the government of Japan. Release time from teaching to enable the project director of lead the effort was granted by the Department of Architecture at Ball State University. In-kind support was provided by Mansur Construction Services, CS&M Contractors, and the Gaylor Group.

Notes

1. See John N. Habraken, *Supports: an Alternate to Mass Housing* (Urban International Press, 2000).
2. See Stephen Kendall and JonathanTeicher, *Residential Open Building* (London: Spon, 1999).
3. See "Housing Conversions," in *Urban Land* (October 2003).
4. See "Converting Commercial Space to Residential," in *Urban Land* (January 2003).
5. See *Rehabilitation Data Needs: A Building Industry Forum.* (Washington, D.C.: U.S. Department of Housing and Urban Development, 2002).
6. See *Environmental Building News* 12 (February 2003).
7. See *Nationally Applicable Recommended Rehabilitation Guidelines*, (Washington, D.C.: U.S. Department of Housing and Urban Development, 1997).
8. See William O'Brian, "A Call for Cost and Reference Models for Construction Supply Chains," IGLC 11 White Paper (December 2002).
9. See Age van Randen, *Matura Infill System.* BV product literature.



CONTENT ANALYSIS OF WEB-BASED COLLABORATIVE DESIGN
Empirical Evidence of design process

Eberhard Laepple,[1] Mark Clayton,[1] Robert Johnson,[1] and Steve Parshall[2]

[1] CRS Center, Texas A&M University, College Station TX
[2] HOK Advance Strategies, Houston, TX

Web-Based Communication Systems (WBCS) are project specific web sites that provide dedicated web hosted "collaboration and information spaces" for the AEC industry to support design, engineering and construction teams. These systems have an underlying software structure that is shared for many independent building projects. A typical system provides controlled access to the project data from any physical location through the Internet. WBCS can have various features, such as email, message board, document repository, calendar functions, to-do-lists, and project administrative features.

The software itself is not new; it has already been applied in architecture and even more in engineering. Current studies indicate that there are over 260 WBCS available on the market (Orr 2004). However, many architects are hesitant to use the new technology and are not convinced of its potential. The concern firms share is that a WBCS may waste time or fail to enable a successful project (Laiserin 2002). The question is: do WBCS tools contribute effectively to building projects?

Current research has investigated several limited aspects of Web-based communication. Previous studies have generally dealt with data from an experimental setting or are single case studies. The objective of this study is to measure the use of WBCS within AEC. This study employs a new approach in AEC research by using data produced as a byproduct of the commercial use of design support software.

MOTIVATION

The architecture industry may be undergoing a major shift in the way it conducts business; it appears to be shifting towards a Design-Build operation, according to Cramer (2003). Firms and teams are working more closely together. As outlined by Cohen (2000), Orr (2004) and Laiserin (2003), integration of technology is required to streamline businesses and support the AEC organizations .

A few companies have already been successful using advanced integrated information exchange to improve their bottom line (Johnson and Laepple 2003). However, the industry still lacks a system that supports the information flow over the entire building project cycle (Alshawi and Ingirige 2003). Some market analysts suggest that WBCS will reach a $25 billion market in a few years (Gartner Group 2001). To reach this level, improvements of existing systems are necessary, but to do so the current use in practice must be known. This research investigates the actual use of these Web-Based Communication Systems to help software developers produce better products and better meet the demands of this expanding market.

PRIOR WORK

Other researchers have investigated the use of Web-based tools applied to architectural design. Engeli and Kurman (1996), Kolarevic (2000), Latch and Zimring (2000) have conducted research on Web-based tools to explore educational settings or small short-term projects. The data in their studies is produced under experimental conditions, such as classroom environments and the conclusions may not be generalizable to industrial applications. Secondly, they are focused on prototype Web tools rather than common applications. In another effort, Verheijn studied the theoretical functions of commercial WBCS, which he considered as "*Teaming, Coordination, Collaboration and Communication*" (Verheij and Augenbroe 2001, p20). In contrast to these earlier works, this study has investigated the actual use of WBCS in commercial architectural and engineering practice.

There have been a number of studies in the field of design methods that target how practitioners work. Recent studies have rarely employed quantitative analysis. A few studies have used an experimental environment or single case studies. Cross has conducted some of the most rigorous research in the field of design activity in AEC industry using protocol analysis (Cross, Christiaans, and Dorst 1996). They observed designers at work and coded their activities by time and category to allow generalization. Another example of protocol analysis studied the stages of analysis, synthesis and evaluation in design process (Purcell et al. 1996). Another research effort has performed interaction analysis on videotapes of a series of design charettes to develop characterizations of how architects use Internet-based telecommunications (Al-Qawasmi and Clayton 2000).

These studies were focused on small numbers of participants and within an educational environment. Our research examines large project teams of actual building projects involving hundreds of designers and thousands of transactions to drive conclusions about design methods.

The categorization of content in these studies is challenging as Verheijn indicated. Malone proposed a more theoretical model, *Coordination Theory*. This theory characterizes coordination as "*managing dependencies among activities*" (Malone and Crowston 1994, p90). However, the application of Coordination Theory to the AEC industry has been limited to primarily theoretical investigations and "empirical studies are clearly needed to illuminate the situation" of the utilization of Internet based project nets (Huang and Tovar 2000). This study combines Verheijn and Malone's definition of coordination and distinguishes the work tasks into coordination and collaboration. Collaboration for this study is seen as: *The interaction of at least two people to achieve a common goal.*

The second content category is information behavior (of the user). What is the participant using the data and system for? Baya and Leifer laid out simple and successful the three steps that can be done with data: Generate, Access and Process (1996).

METHODOLOGY

This study applies a multi-method approach to generate a clear image of the use of WBCS. It employs the following steps: review of previous research, and analysis of data of actual building projects. Qualitative interviews are planned but have yet to be conducted. Briefly, the study is organized in the following steps:

- Review published literature.
- Identify partners from industry.
- Collect transaction records from firms.
- Code records by transaction form and content analysis.
- Statistically evaluate frequency of coded values and find correlations.
- Synthesize analytical results to produce conclusions.

The crux of the research method is to analyze the data that is automatically collected by WBCS during real-world projects. Data from six projects led by three different AE firms has been collected, resulting in a dataset of over 50,000 messages. More detail on the sample is provided in the section on Description of Cases.

RESEARCH QUESTION

The existence of this dataset has led us to postulate a large number of research question that can reveal how WBCS are used and what they can achieve in architecture and engineering projects. The basic research question (Do WBCS tools contribute effectively to building projects?) can be decomposed into a number of quantifiable sub-questions, some of them discussed herein are:

Is Information Flow Driven by Senders or Receivers? Traditionally, the sender directly addresses information to the receiver via letter or email, but a WBCS can be used as broadcasting tool. With the introduction of a common repository it seems that the receiver determines which information to retrieve (Monge et al. 1998). A study of transactions may determine how much information is sent directly for quick attention and how much information is posted for the convenience of the receiver.

Is the Use of Functions Dependent on Type of Information to Be Conveyed? Each role in the design and planning process must accomplish different types of work. In theory, different software functions (calendar, document repository, message board, email) may be more appropriate for each kind of work. For example, while a project manager has to coordinate and communicate, an architect may be more likely to use collaboration. The transaction logs can be searched for a correlation between user role and channel of communication.

Does Information Type Change Over Time? Different stages of a design project may involve different types of information. By coding the transactions recorded by the WBCS by information type, it is possible to study the frequency of transactions in relation to project stage.

Does Location of Office or Participant Influence the Use? One would expect that if a user is geographically outside a metropolitan area, away from the main offices or other central locations, where participants physically meet would use it more frequent.

Does Software Hierarchy Equal the Organizational Hierarchy? WBCS have been developed as non-hierarchical tools that allow anyone on a team to easily communicate with anyone else. Have architecture teams adopted this non-hierarchical, flat organizational model or do they work in a more traditional hierarchy? By studying the sequence of messages and transactions as they are relayed through the system it may be possible to reach conclusions about the form of the organization.

CONTENT ANALYSIS

Several of these questions depend upon an analysis not only of the transaction type and time, but also the content of the information communicated. Content analysis has been conducted to investigate these issues. The unit of observation is a transaction record in the WBCS. Each time a participant sends a message, confirms a transaction, or uploads or edits a file, the WBCS documents the access to the data and marks entity (log entry). The entity has associated variables such as content type, time, and roles (sender and receiver).

The goal of every quantitative analysis is to produce counts of categories and measurements of the amounts of variables. The variables chosen are of manifest content of the data; they can be read directly from the message, since elements are physically present and countable (Gray and Densten 1998). The study differentiates between two types of variables: form and content.

FORM VARIABLES

The three form variables are source, channel and receiver. The *Source* reflects the sender of the information. It is measured as a nominal variable [nominal]. The *Channel* stands for the channel of exchange, which is the function that has been used to relay the message [nominal]. The number of nominal categories is determined by the system analyzed. The *Receiver* of a message is the participant or role to whom it is addressed [nominal]. The form variables rely on hard, objective data inside the actual message that describes the form of the message transmitted.

CONTENT VARIABLE

The fourth variable message is a content variable. The messages are investigated for their content category [nominal], timestamp [interval], task of message [nominal] and information behavior [nominal].

The content variable classifies each message into a priori categories that are developed according to existing literature. Because there are many theories of design that name and distinguish activities within the overall process, the research employs many categorization variables. Each transaction is assigned to a design strategy, which follows from Asimow (1962). These categories are analysis that describes the problem, synthesis that generates a candidate solution, evaluation that assesses the viability of a candidate solution, and administrative issues. Nevertheless, before the detailed coding scheme is finalized, professionals were asked to comment on the coding, preventing gaffes. The goal is to generate a set of complete and unambiguous categories.

EVIDENCE FROM CASE STUDIES

A perfectly representative sample is impossible, since access to this data is limited. In many firms, like software companies, the owners and the architects are hesitant to provide unfiltered confidential information of this kind. They are afraid of losing competitive advantage, providing proprietary data, and or legal disputes. These are obstacles obtaining a random sample and having access to the full target population. Inevitably a study such as this one will employ convenience sampling. Three firms have agreed to share information about past building planning/ design projects.

Since the availability of data determines the building type to be analyzed, a strict limitation to one type of building project is not feasible. In personal discussion with the researcher, high ranking administrators of the companies selected projects, from which the sample has been drawn.

DESCRIPTION OF CASES

Three major architecture firms, listed among the top AE firms, provided their WBCS communication repositories from the planning, design and construction documentation stages of building projects for six case projects. Each case consists of up to 20,000 recorded messages or transactions. Each project team has about 50 interdisciplinary members, who perform a variety of roles in the project, such as client, architect, contractor, engineer, and consultant. All messages, transactions, and documents that have been posted, submitted, or reviewed have been loaded into one joint databases.

All six cases have in common that they deal with high-end office or retail spaces and that the construction costs are each above 10 million United States dollars. The complexity of the projects required communication among large teams of participants over several months. The data includes all written or electronically exchanged documentation for each project.

Cases 1 and 2 cover the pre-planning until project execution phases for office buildings for telecommunication firms. The duration of observation is 50 weeks for each of these cases. Both cases involved in-depth considerations regarding future operations and flexibility of use.

Case 3 covers the planning and design stage for a series of retail and commercial office buildings in a metropolitan setting, and has been investigated for 75 weeks.

Case 4 is the design and documentation phases of a corporate headquarter for an insurance company, lasting 38 weeks.

Case 5 covers 12 weeks of the design documentation phase for a mixed use high-rise building that includes retail floors and office spaces.

Case 6 documents 50 weeks of communication from the design development until construction administration phases of an urban retail building. One limitation is that not all emails that have been exchanged were available, due to the fact that team members used a corporate mail server that was not integrated with the WBCS functions. Since verbal communication and face-to-face communications could not been captured over a long period, written meeting agendas and meeting notes were provided by the firms. In further research that is not yet complete, we will conduct a series of interviews to account for the verbal and undocumented exchanges.

SYSTEM DESCRIPTION

In the six cases, the three AE firms used two WBCS that are typical of those on the market. Both systems provide common functions of file repository, calendar, team directory, and project message board. Members log on and are authenticated, and then the system records each action. Participants have an assigned access level with specified privileges such like administer, change, write, or view. However, none of the firms had limited its member's privileges, with the exception of the project client's access rights in Cases 1 and 2.

System Type A is a proprietary system, developed by an architecture/ engineering firm and used in-house as well as sold to outside clients. It has additional functions of a threaded discussion board and a link list to outside information.

System Type B is a commercially available software package. It provided additional functions for managing Requests for Information (RFI) and Submittals, with version control of all digital documents. It also has a built-in email function, which was not used.

Some candidate projects were eliminated from the study because the software provider would not consent to objective testing without prior guarantees.

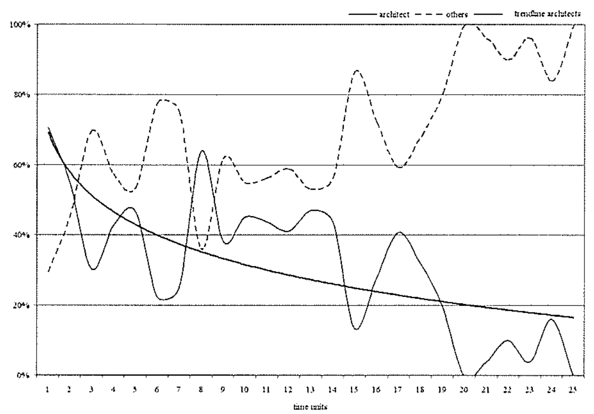


Figure 1. Contributions by firm over time: Case study 2

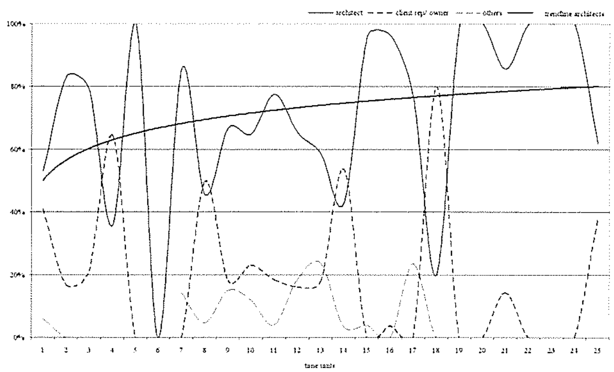


Figure 2. Contributions by firm over time: Case study 6

DATA ANALYSIS

ROLE OF PARTICIPANTS

The majority of document and transactions have been submitted by architecture firms and their employees. The percentage of transactions changes from week to week. Below are two sets of typical curves. Cases 1 and 2 describe projects in the early design stages, such as strategic planning and schematic design (Figure 1). In these cases, the amount of architecture contributions is steadily increasing. The communication by non-architects is mainly from owner representatives. Cases 4 and 6 are projects during the construction documentation and administration phase (Figure 2). Both charts indicate a decreasing amount of contributions from the architect, while the number of contributions by particularly engineers is increasing.

All cases, but Case 1, clearly indicate the ping-pong cycle of communications and interactions among the firms. Typically, one group, such as the architects, proposes and discusses a solution in-house and then passes it on to the next group, such as engineers or consultants. This pattern explains the ups and downs along the time line: there is strong activity in one group while low activity in the other group.

HIERARCHY WITHIN FIRMS IN RELATION TO SYSTEMS USE

At the beginning of all efforts is the question "who is going to do the work?" To answer this question in more detail beyond the firm level, one main question this study tries to answer is; which work tasks are performed by whom? Dividing all messages and transactions based on content analysis into collaboration and coordination tasks, the following picture can be drawn in relation to the hierarchy of senders of each messages.

Tasks	Exec.	Direct	Lead	Speci.	Intern	Staff	
Collaboration	11.9%	15.0%	16.0%	23.8%	0.0%	33.3%	100%
Coordination	6.3%	13.4%	25.7%	35.9%	4.0%	14.6%	100%

Table 1. Task versus Hierarchy of Employee.

Inform.	Exec.	Direct	Lead	Speci.	Intern	Staff	
Access	4.1%	15.8%	20.1%	45.7%	2.5%	11.9%	100%
Generate	7.1%	12.6%	27.3%	23.6%	5.1%	24.3%	100%
Process	6.5%	22.0%	36.2%	15.1%	0.4%	19.8%	100%

Table 2. Information Behavior versus Hierarchy of Employee

Coordination takes place primarily in the mid-range of the hierarchy, such as among lead engineers and specialists (Table 1) (Laepple, Clayton, and Johnson in print). Collaboration or exchange of information takes place at the specialist and administrative staff level. One might say that the specialists produce the results, but are coordinated by their leaders and directors.

Although the software supports non-hierarchical interaction among team members, most information is routed along company hierarchy lines rather than directly to the ultimate receiver. The software design does not match the organizational form. Nevertheless, it has to be considered that a highly ranked employee in the firm usually is assigned to more than one project at a time and might therefore not contribute as many messages to a single project.

Table 2 further indicates that most of the accessing or reading of electronically available information is done on a specialist level (Laepple, Clayton, and Johnson in print). The messages or information is then worked on and presented outside the WBCS to the team leader. The team leader then feeds the newly generated information into the system. Based on the log information, team members frequently send "new" or "process" information to their staff assistants for submission and distribution. This is similar to the traditional way of doing business by delegating tasks to subordinates who can monitor the flow of information into and out of an executive office. The teams in the cases have not made use of the capability to send information directly to the intended final receiver.

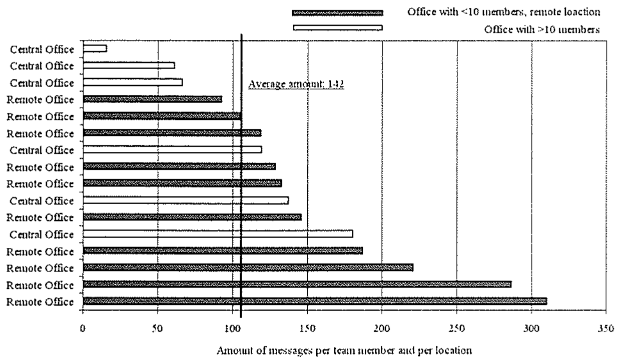


Figure 3. Average amount of activities per user and time unit, based on their location

ACTIVITIES IN RELATION TO LOCATION

The above two sections answer, on a quantitative level, who is doing the work. This section considers the impact of whether a participant is in a central location or in a remote or client site location. Some participants were located at central offices, while others occupied branch office facilities. For this study, central offices are considered those that have over 10 project members or are part of the corporate headquarters of a firm.

The use of communication through WBCS is more than twice as frequent among firms as within firms (Figure 3). Similarly, remotely located team members contribute over twice as many transactions than members located in headquarter offices. Cases 1 and 2 (which are reflected in the figure) involved multiple offices of international firms, consisting of architects, engineers, planners and consultants. Each participant averaged 141 transactions over observed period. Members of remotely located offices that had a small number of team members at the office or were in non-metropolitan settings used the system more frequently, with up to 310 transactions. This result is not surprising as members who are geographically far from the primary location for the project would rely more on telecommunications, include the WBCS.

THE INTENDED RECEIVERS OF INFORMATION

A significant difference among messages is whether they have an intended receiver or not. If they have an indented receiver, are they addressed, routed or sent directly to the intended role or group? The software provides functions that have informative character to the entire project team, such as announcements, link lists, and are posted to the WBCS site without an intended receiver. A second group of WBCS functions includes documents, emails, and notifications that have or should be directly send to a receiver.

In the cases studied, the software appears to have influenced the routing of the information. System B had a default setting, which demanded a concrete receiver named. In System A, a receiver was not required to be specified to submit information. Based on the quantitative data, Case 5 and 6, which employed System B, used mainly defined receivers (70 percent of the messages), partially due to the fact that it involved many RFIs. Case 3 and 4, which employed System A, used the entire system as a document repository, but with well defined indexes. The system was used as a "pull system;" it is up to the unspecified receiver to "find" the information needed. Case 1 and 2, which employed System A, used a system of categories in which each document was classified. The users knew the category for which they were responsible and could browse the repository by the latest entries. "None addressed" messages and announcements were always linked from the opening webpage.

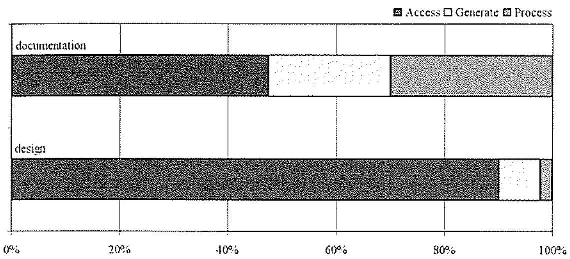


Figure 4. Information behavior during design development stage verse construction documentation

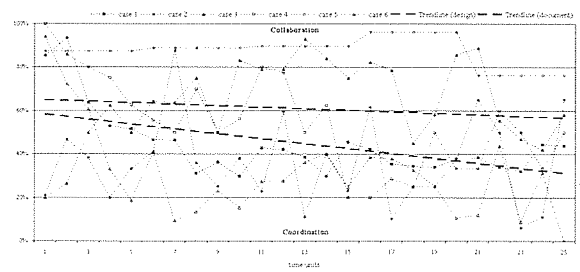


Figure 5. Changes in ratio between coordination and collaboration over time

SHIFTS OF INFORMATION BEHAVIOR

The difference between stages is also apparent from analysis of the kind of activity. (Figure 4) shows the proportion of activities grouped into classifications of "access," "generate," and "process." Across all cases, the majority of all transactions are only accessing information and do not contribute new information to the information pool. Ninety percent of the activities in the early design stages are accessing information for reading and assimilation. In construction documentation, only 50 percent of activities were for accessing information, as illustrated in. Generating new information and processing information accounts for the remainder of transactions.

With progression of the project, the information type changes from pure messages, review of background information, and negotiations to more output and production oriented information. The study shows that the main production of new issues or documents, such as drawings and detailed descriptions of the building, is accomplished at the later phases of the projects. Also, the involvement of the owner is lower towards the later stages of the project.

An actual tracking of the change in information type over the project life cycle requires longer observation of each case. Not all cases have yet gone through all stages of design, construction, and operation. Further study is collecting additional information that may allow a more complete picture of which information is used over the project life.

VARIATIONS IN WORK TASKS

As the industry globalizes, collaboration becomes a core requirement. The practical reality is that collaboration requires a higher order of involvement and a different approach to sharing and creating information; "collaborative environments have to be created" (Schrage 1990). To enable coding of the data, the study uses the following definitions for each:

The dimension of coordination versus collaboration provides additional insights. (Figure 5) compare average percentage of coordination activities below the line and percentage of collaboration activities above the line for all cases. Since each project was studied for a different duration, the total time for each case has been subdivided into 25 equal "time units." The figures also show a trend line and extremes. The two figures differentiate between cases that were oriented toward the planning and design stage versus cases focused upon construction documentation.

From the graphs, several conclusions can be drawn. Group coordination messages are the most frequently observed category at the project inception and within each project stage itself. They decline in frequency with the progression of the project while the collaboration messages increase. Progression from coordination to collaboration parallels a change in software functions from "pure messages" to "task assignments" and further to "documentation." The appearance of flurries of message of one category type within a phase characterized by another category type needs still more study. (Laepple, Clayton, and Johnson in print)

The figures document a qualitative difference between the two types of cases. In planning and design cases, illustrated in (Figure 5), the proportion of coordination activities decreased dramatically over time. It begins at 70 percent and then declines to below 40 percent on average. In the cases focused on construction documentation, shown in the mix between coordination and collaboration, stayed more constant for the duration of the project, declining only slightly.

This difference in shape of these curves suggests that the distinction between early and late design is an accurate model of design processes. Perhaps, in the cases with more coordination, the constructor was already involved. The involvement of new participants probably requires a great effort of coordination prior to collaboration.

SUMMARY OF OUTCOME

The research has produced evidence regarding who participates at various stages of the design process, how they use information, and how they share information throughout the team. The data confirm that a WBCS is most useful in distributed organizations and may be most critical to branch office operations. Coordination efforts are particularly important in the early stages of a project, while collaboration activities dominate at later stages. From the cases studied, one can conclude that the planning and design stage exhibits a high degree of coordination at the beginning and proportionally more collaboration later, while construction documentation exhibits a more consistent split throughout the process. The planning and design stage is overwhelmingly dominated by access operations to the information rather than generate operations or process operations. Construction documentation is more heavily characterized by generate activities and process activities. These observations lend credence to design method theory that distinguishes the design process into distinct stages.

The different categories of employee require different functions and support. While high-level employees, such as executives and directors, make relatively small use of the software, the bulk of activities recorded by the WBCS are performed by the specialists, lead professionals, and staff. However, executives and directors undertake access, generate, and process functions, indicating a wide range of expertise and responsibility.

NEW RESEARCH APPROACH

Logging the use of Web-based communication for research purposes has not previously been conducted at this scale. This research uses existing data from practice at a large scale to support content analysis of design activity. It is uncommon to conduct quantitative research in communication in architecture using samples from practice, but it has proven to be promising. Independent of the actual outcome of the analyses, future research can adapt this method and conduct more detailed studies in the area of AEC. The use of transaction logs from Web-based software is a new form of design research that produces highly reliable and valid evidence in the field of design methods.

ASSESS ADEQUACY OF WBCS WITH RESPECT TO THEORY AND SUBJECTIVE ASSESSMENT

This research produces comparisons between Web-based Communication Systems and theory relating to this technology. This provides reasons to adjust the software or the business organization. The research documents the subjective assessment of users towards the WBCS. This provides evidence for the AEC industry and or the software industry regarding how the communication systems are designed and implemented in this field. The research may lead to new theory of design process or modification of existing theories.

COLLABORATIVE DESIGN PRACTICE AND IMPACT ON THE PRACTICE OF ARCHITECTURE

The entire study is based on records of actual communication among participants in the AEC industry. The research produces an image of how collaboration is conducted currently in practice, in particular using digital means of communication. The research indicates a frequent mismatch of the WBCS with the organizational structure. While the WBCS are designed to facilitate flat organizational structures, the design teams in these observations use traditional hierarchical structures. Either the organizational structure or the software should be adjusted.

LIMITATIONS OF STUDY

The conclusions are based on a quantitative content analysis. Hence, back-channel communication has not been addressed. The face-to-face and back-channel communication is part of continuing study with the same industry partners. The future study may show what information is not transferred by the system and why.

OVERALL SIGNIFICANCE

The building sector is entering a new era. Developments in ICT have an impact on the entire building life cycle as described by Jabi (2000), and Johnson and Kolarevic (1999). More knowledge of IT use in the AEC is needed; this study contributes to this body of knowledge.

The research explains vital characteristics of the AEC industry. This may increase the productivity and the quality of architecture projects, in a future where IT becomes more vital than ever before. The documented communication patterns could support efforts to model flows of communication and collaboration in the future.

Currently, the majority of architecture firms could technically utilize WBCS, since the systems are readily available on the market, but many firms are skeptical. The research leads to several suggestions regarding how to improve WBCS software and its use in practice. The analyses indicate that a clear routing of information is often not provided either by the user or by the software. It may be appropriate to change the software or adjust the organization workflow by encouraging clearer routing by the senders. Too much time may be wasted if receivers have to look out constantly for messages that could be of importance to them.

If patterns of communication in the AEC industry are better known, more advanced software can be developed to support AEC work structures. From this research and further studies, the AEC industry can gain a better understanding of requirements of software, reduce barriers of acceptance, and reduce potential for data loss during communication. Better software will increase the speed of project processing and lead to financial gains or savings for the industry and owners.

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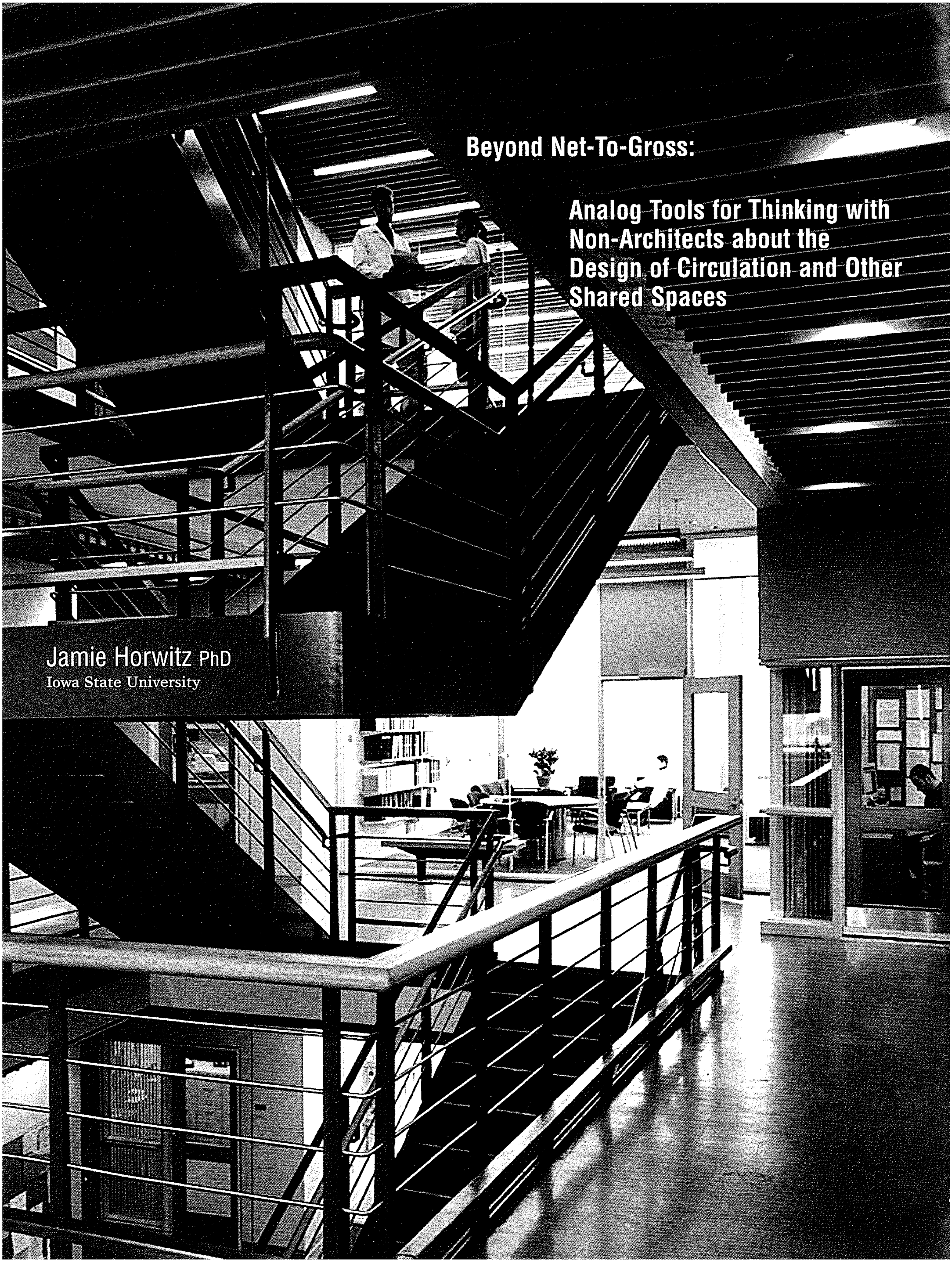


Beyond Net-To-Gross:

Analog Tools for Thinking with Non-Architects about the Design of Circulation and Other Shared Spaces

Jamie Horwitz PhD
Iowa State University

I. Introduction

Among the challenges facing contemporary architects today is a growing public interest in evidence-based design. As recently reported in the AIA Journal evidence-based design is a "rigorous, hypothesis-testing" approach to design practice that builds on a literature of user-oriented building evaluation research (post-occupancy evaluation research or POEs).[1] Bringing the authority of scientific method into design practice, we are told, will be the next qualifying standard among firms.[2]

A designer's desire to lend the authority of science to the art and pragmatics of building is understandable. So are a client's desire for greater accountability and less uncertainty when selecting an architect, establishing a budget, negotiating a design, and most of all, deciding to invest in facilities rather than in people or services. Everyone wants to decrease his or her exposure.

Design conventions that evolve through iterative refinement and empirical evaluation are likely to be better—and any approach that welcomes research into design practice is promising—for society, for the environment, and for a person like me who is likely to find more room at the table. Yet, the idea that science trumps architecture troubles me. In the multivalent context of design decision-making, I fear the results of a process in which architectural thought could be effaced in the name of 'evidence'.

As firms reflect on contemporary challenges and opportunities, some are questioning conventional models of practice in a knowledge-oriented service economy.[3] The inter-relationship of design, research and strategic services is leading some architects to recast their firms into an 'ideas company' in which professional practice can lead or follow client-centered consulting contracts.[4] Whether or not models of practice change, today more and different types of expertise participate in all levels of design decisions.

Will the new mix of services make for better buildings, better cities, and better environments? I believe that depends not only on bringing new knowledge into design decisions; better environments depend on bringing the inherently integrative thinking of architecture into design decisions that are, all too often, made without architects.

For example, the simple calculus of 'net to gross' might be characterized as one kind of evaluation tool that is used to replace thinking rather than be a tool to think with. The 80/20 standard ratio is a means to determine the square footage efficiency of those areas assumed to provide a return on investment.[5] Buildings as different as low-rise, office parks, retirement homes, and junior high schools are all too often subject to the same measure and stick, despite the very different role that 'non-revenue' spaces, such as circulation, play in the different building types. In this sense 'net to gross' could be considered an un-tested hypothesis that needs to be rigorously evaluated and fundamentally challenged.[6]

The means by which clever designers overcome the constraints of 'net to gross' could, on the other hand, be considered a school in itself. As an outsider to the traditional world of practice, I find this 'schooling' one of the secret codes that no amount of reading or building evaluation research would have helped me understand. It is not that 'net to gross' is so elusive, but I have experienced it as a kind of shadow that is cast over, what I consider to be, the most critical social factors in a building—the way that it connects people, and connects functions.

This paper is a product of multiple sources and methods of inquiry. They consist of:

- the architects who brought me as a researcher into their firms, introduced me to clients, and building committees, and communicated some of their design intensions regarding the circulation design that animates the interior life of the projects I would study,[7]

- on-site studies of completed projects in which I observed, interviewed, and surveyed those who live and work in these buildings,

- multi-disciplinary literature about networks that comprises social networks, spatial and built networks, and network theory. This includes as well, the architectural history of passages through buildings, the evolution of the corridor, the sociology of networks people establish with one another, and as groups, the difference that physical environments make to these networks, and analytic tools that I use to study the spatial, and therefore social connections that architecture creates in cities, on campuses, and within buildings.

The purpose of this chapter is to weave these forms of evidence through the context of one extremely successful building project in order to demonstrate retrospectively, and hypothetically, how architectural ideas and spatial thinking might engage the 'evidentiary' basis of design decisions. Design deliberations represent a form of intellectual engagement that can:

- provide arguments for linking design solutions to the substantive issues about the client's activities, strategies and goals,

- bring historically significant material into the discussion, and make the evolution of architectural thought more visible and audible to the non-architects at the table,

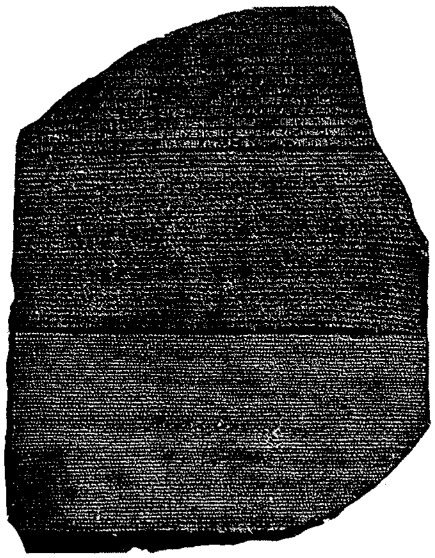


Figure 1 The Rosetta Stone

- reveal the intellectual tools of architectural design, especially their capacity to puzzle through problems and to arrive at spatial solutions by demonstrating thinking through the use of analog tools that are infinitely adjustable, more like slide-rules than digital calculators.

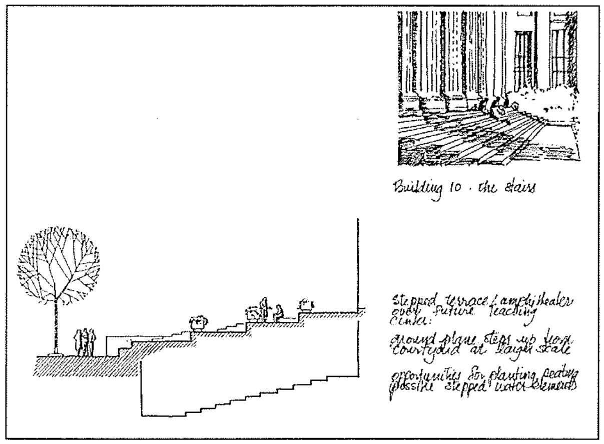
I call these analog tools, in that they are tools to think with and to share one's architectural thinking with non-architects.

2. The Rosetta Stone Model:
Architecture collects languages that are 'out of sight'

The Rosetta Stone is perhaps the greatest example of an analog tool. A black slab of basalt dating from 196 BC, it was inscribed by ancient Egyptians with a royal decree: once in Egyptian, once in hieroglyphic, and once in Greek.[8] As a tool for deciphering hitherto unknown languages, the Rosetta Stone has become emblematic of something that makes evident what had been obscure until now. It so happens that this analog tool has also been used to describe the architectural project on which this chapter is focused (figure 1).

Figure 2. Perspective drawing showing Koch on the right, and Pei's Landau building in the background.

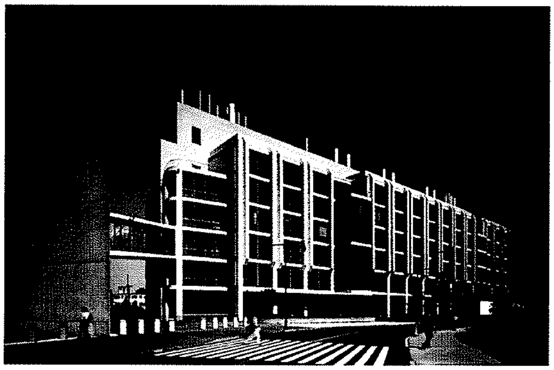
Figure 3. Goody Clancy proposal drawings of Koch exterior steps and drawings of steps on the original MIT buildings by Bosworth.



Richard P. Dober, in *Campus Architecture: Building in the Groves of Academe* (McGraw Hill 1996) describes the Massachusetts Institute of Technology's Building #68, or Koch Biology—completed in 1995 by Goody Clancy Architects—as follows:

> [The building is a] watershed structure in campus design at an institution whose eastward expansion is a model of sound campus planning and adventuresome architecture. A century of exemplary American higher education buildings can be found in the precinct, produced by the leading architects of their time. These include ... among the notables. The Goody Clancy design is an architectural Rosetta stone. The shapes and textures in their felicitously modulated facade are derived and combined from older campus buildings, and can be read and translated as the architect's code of hierarchy and importance.

Figure 4 Koch and Pei building



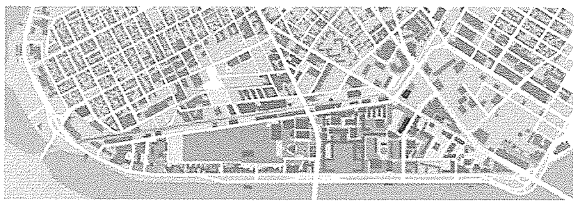


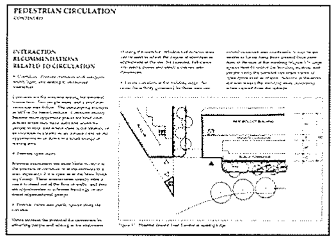
Figure 5 Plan of northeast MIT campus indicating the intersection of grids

Dober's laudatory remarks point to the exterior expression of the Koch Biology building, and makes reference more to the original buildings by Bosworth (1916-1939)—on the other side of campus —than to I.M. Pei's Landau building(1974), its nearest neighbor (figures 2 and 3).

For example, one of these references can be found in Goody Clancy's three-dimensional expression of the repeated vertical bays on the facade, rather than a more monolithic, taut envelope with cut-outs. The finely made, well-proportioned Pei structure next-door is a sculptural, stand-alone building with a small footprint. As such, it does not suggest the changeability or expandability Goody Clancy wanted to express with the Koch Biology building. However, Pei's design made a bold and "brilliant shift in the grid"—as Roger Goldstein, a design principal in Goody Clancy explained to me; a shift away from the grid established by the River and Massachusetts Avenue, and toward Main Street and the railroad lines. The Koch building followed Pei's shift, orienting the biology buildings and northeastern campus toward Main Street, and what has become a massive district of bio-technology development (figures 4 and 5).

Figure 6 Koch pedestrian circulation.

Figure 7 MIT campus circulation plan in the early 1990's provided the context for the Koch Biology Building design



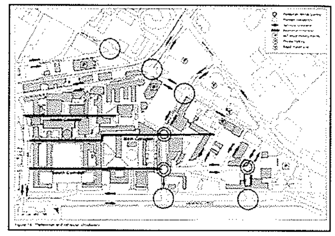


Figure 8 View showing the porous vertical circulation node intersecting with the horizontal lounges and tea rooms

While not reflecting the surface appearance of Landau, Goody Clancy's design physically reaches out to its neighbors as it sends out a bridge element between the Biology building and the Landau Chemical Engineering building on the third floor, as well as tunnel to the Cancer Research Center, maintaining the interior passageway known as "MIT's Infinite Corridor"[9] (figures 6 and 7).

The Koch Biology Building's interior circulation, and particularly the 'core'—as Joan Goody refers to the vertical circulation nodes—is itself a Rosetta stone that transfers and translates research on the socio-spatial networks between research and practice (Figure 8).

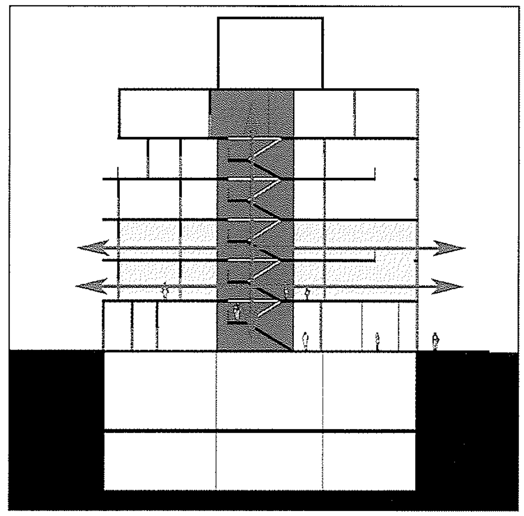
In what follows, I develop examples of evidentiary arguments linked to the design of the Koch Biology Building 'core'. Needless to say, these are my own retrospective reconstructions and not those of Goody Clancy. They are used as a demonstration of using analog tools in order to make translations between research and practice—in this case resulting in an extraordinary zone of connectivity from the most carefully controlled access to the most publicly accessible space, and at every point in between.

3. a. Research:
The history of interior passages or buildings without corridors

In his essay "Figures, Doors and Passages," the late architect and historian Robin Evans traces the evolution of something so familiar we take it for granted—the interior corridor. Unable to find, prior to the 1700s, evidence of the most commonplace model of a corridor with single-entry rooms off of it, Evans shows us that in palaces as well as farm houses, people simply moved from room to room. Room-through circulation means that rooms must have multiple doors (when the doors are aligned we call the string of spaces *enfilade),* and there is, also, an unavoidable mingling of activity with what we now call traffic.

Evans shows us that the way through a building was and continues to be un-related to architectural style, yet it always affects the way we occupy a building, and the "style" of living or working there. Making observations from building plans and paintings, Evans hypothesized that the emergence of corridors as a means of removing traffic from rooms and into single or double-loaded corridors occurred because of a desire for more controlled access, particularly to avoid servants knowing the business of their employers. The effect of removing passage from place, Evans fears, is that buildings can become void of the conviviality that derives from the access and mingling of activity and movement.

Figure 9 Author's drawing showing stacked enfilade section of Koch core (red) and horizontal enfilade of lounge-staircase-lounge (yellow)



The possibility that visually porous circulation could be designed in section as well as in plan first came to my attention in the context of a planning and programming study for the Iowa State Memorial Union.[10] Completed in 1929, the building's formal procession space was bisected on the main floor by an entrance hall (in memory of students who had died in wars), while a chapel, reading room, and eating commons are located below grade.

Over forty years and eleven additions, in which room after room was slapped on to the east and south facades, the original axial organization had become entirely embedded in a dense labyrinth of space that made no effort to link back to or amplify the original circulation pattern (figures 9 and 10). After surveying more than a thousand students, interviewing faculty and staff, the data clearly indicated that the confusion over the location of activities, and spatial orientation in the building, kept its inhabitants from exploring this campus treasure house that alumni continue to describe as a "chateau on the prairie."

Figure 10 The genealogy display context in Koch core

But evidence of a problem does not a solution make. Reflecting on the building and the data with my collaborator, Professor Michael Underhill (at that time Chairman of the ISU Department of Architecture) pointed out that the confusing circulation in the building might only be solved by something as radical as blowing holes through the floors to open up a visual and spatial connectivity.

3. b. Design strategy: Inflecting axial plans into section

The vertical core designed by Goody Clancy for the Koch Biology Building resolves this kind of problem by surrounding the intersection of horizontal and vertical circulation with glazed rooms that together form a stacked enfilade system (figure 9).

At first sight, the vertical circulation core appears to function as a friendly node between the controlled access of individual laboratories and the uncontrolled, public access to the faculty offices, and gathering spaces of students, scientists, and visitors to the building. When I interviewed several of the distinguished senior scientists who had been members of the Koch Biology Building committee, I learned that the committee had pressured their architect with an over-arching requirement that eventually shaped the design. Bob Sauer, the Biology Department Head, explained to me last summer that:

> we told Goody Clancy that we wanted a design that made it impossible not to see other people all the time. You didn't have to interact with them. You could be as grumpy as you wanted. But you couldn't go through the day only running into people in your own labs.

Goody Clancy responded with an elegant and visually porous vertical circulation core in which staircase and elevator wrap around seminar rooms, faculty offices, restrooms, and "tea rooms". A legacy of senior faculty who had trained at Cambridge University labs, these meeting rooms, with their kitchens and white boards, work as impromptu meeting places for conversation, cooking, and eating.

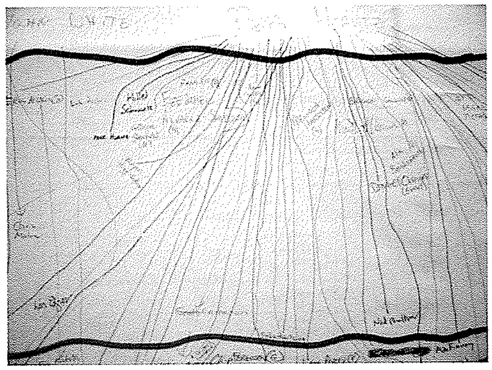
By shifting the floor height from eight feet in the lab corridors to eleven feet in the core, the design shifts attention upward toward a wood ceiling grid and the transparent staircase elements. The warm color and feeling of the wood and the natural light from the surrounding windows through the glazed rooms contribute to the un-laboratory-like character of the gathering and circulation node. Here the overlapping of activities from the lab suites, the ease and beauty of the staircase also support the location of amenities, where one goes to the bathroom, gets a drink, meets in groups, and takes a meal break.

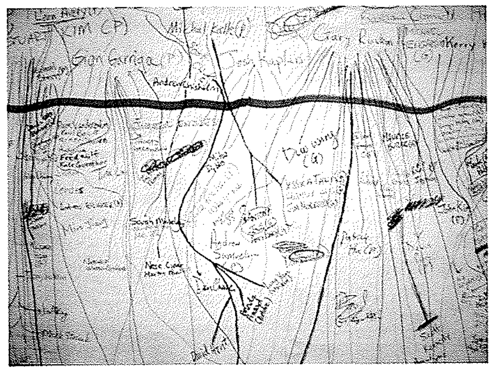
A threshold in the vertical core improves connectivity between labs, an incentive for taking the stairs, and reflects the tradition of having tea in the community of science.

The enfilade stacking of shared spaces around the vertical circulation in the Koch Biology Building 'core' amplifies the allocated footage for circulation, contributes to the increased concentration of social interaction, and adds a transparent sense of spatial orientation in this large building. But there is more worth noting and teasing apart.

These multi-junction nodes appear to have the use pattern and vitality of a vernacular space—a common shared space by the whole community. How do I know?

Figure 11 and 12. Details of genealogy maps.





4. a. Research:

A common is a rule-based pattern of activity in an easy-to-reach location, not an elaborately designed place at the hierarchical center.

A "common", as J.B. Jackson defined its historical meaning:

> was not simply a village grazing area; it was a vernacular space. A vernacular space, unlike a planned and carefully designed public or civic space with its political overtones, is one that comes into being and is formed by the daily customs and needs of the families who live nearby. It serves a variety of useful, temporary functions, none of which is permitted to transform the area in a permanent manner.[11]

4. b. Design Strategy:

Leave room for improvisation at the intersection of primary and secondary nodes.

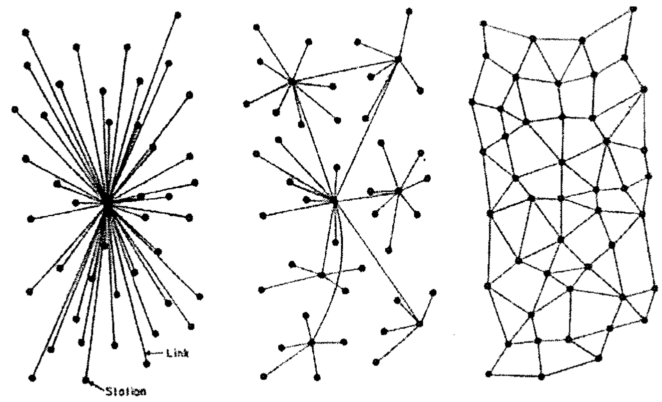
Can vernacular spaces be designed? Must they only be out-growths of the right conditions, or the absence of prohibitions and constraints? While there is room for argument here, the observed behavior and physical traces—standard methods of data collection in design research—can point to the role of a setting in the life of a larger community.[12] Such traces, and the settings in which they are found, offer methods for discovering how places work, and how their understanding can guide new design.

Physical traces of behavior in the Koch Biology Building's vertical core provide evidence of the patterns of use in a common that is a vernacular space. One clue comes from the graduated levels of ownership and display on the glass surfaces facing the staircase and landing area. While notices are taped to interior and exterior doors to explain the rules and schedules of a specific laboratory like problems of shared food, clean-up, and so forth, the glass walls contain political posters. If a designer learns to read 'physical traces', they may in fact add up to quite a bit more than merely some clutter on the wall.[13]

During my visit in June of 2004, I noticed that facing the staircase, and covering part of the seminar room walls, hung pencil-drawn diagrams of the intellectual genealogies of MIT's community of science (figures 10, 11, and 12).

The intellectual genealogies are, in a sense, maps that trace individual paths in a larger network. Not just the collective 'personalization' of a workspace, these maps represent evidence that individuals view themselves as part of the "community of science," and the Koch Biology Buildings vertical core as their "vernacular common."

Figure 13 Figures from Baran's showing three network types



By posting these maps on the public side of the seminar walls is evidence that users perceive and use this as a vernacular space—a common. My hypothesis is that Goody Clancy designed a vernacular space for this biology community by forming a junction—both elegant and rough—between a secondary or 'local' node (laboratory gathering space), and a primary or non-local node (the vertical circulation).

5. a Research:

Historians of science and technology as well as strategists of public policy and defense demonstrate three fundamentally different types of network configurations and their associated capacities for social control and physical access.

The issue of physical access, communications and social control are always present in discussions of networks, whether the subject is building passages and corridors (such as those studied by Robin Evans), the regional infrastructure of highways, or global communications systems.

Strategy analysts, who study patterns of growth or destruction to gather evidence for modeling reliable projections, describe three fundamentally different types of networks: centralized, decentralized and distributed (Figure 13). These are conceptual models, without scale. And they immediately call to mind the underlying configurations of large buildings and building complexes.

The three network diagrams in figure 13 come from the 1964 report "On Distributed Communications," written by Paul Barans for the RAND Corporation.[14] One of a series of reports influential in developing Cold War public policy, they were intended to inform strategic planning of vital resources in order to protect United States industrial capability in the event of a first-strike by the Soviet Union The centralized and decentralized networks are portraits of vulnerability. Safety has only one configuration and that is dispersion.

Barans was an electrical engineer and his job, explains Peter Galison, the historian of science and technology:

> was to ensure the survival of the United States telecommunications infrastructure through a Russian first strike—a vital link not only for domestic communication but also for command and control. His response...was a plan to remove completely critical nodes from the telephone system. Like the three highways many wanted from each dispersed defense plant, Baran's vision aimed for safety in redundantly connected, spatially distributed mini-centers.[15]

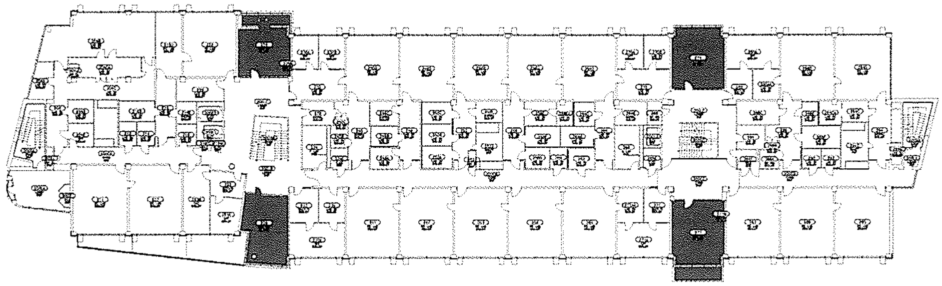


Figure 14 Plan showing lounges in Koch Biology

The redundancy of both nodes and connections is a model of connectivity that is referenced in many different literatures today. One reason for this is that Barans' model of a distributed network conceptually re-engineered the telephone network, and he is credited with theorizing the internet, or what one physicist describes as "an incredible insight...[that] the ideal survivable architecture is a distributed mesh-like network."[16]

But how do the properties of a more distributed network operate as a built architecture (rather than as computer or internet "architecture")? This is the research question that I will pursue in the future. A series of circulation design evaluations I conducted in full-service retirement communities provide my initial response.[17]

A building may be designed in such a way that residents inhabit a distributed network of social/spatial connections without the building looking like a non-hierarchical mesh, particularly not in plan.

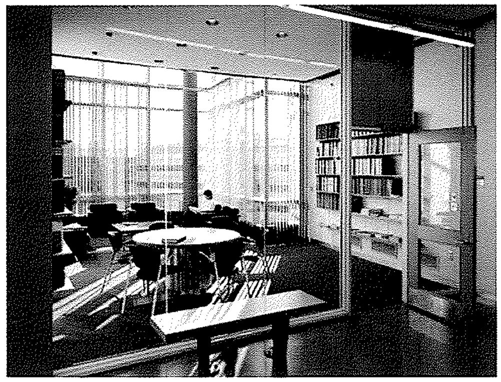
5. b. Design strategy:
Enhance, differentiate and disperse, multi-access secondary nodes.

The model of connectivity found in a distributed network appears to be consistent with a building in which secondary nodes are located on primary paths with high visibility, access, and where they are sufficiently differentiated from other types of gathering spaces, as well as differentiated among other all-community spaces. This pattern is proven in my retirement community design research, and it is suggested by observations and interviews at the Koch Biology Building.

The vertical core in the Koch Biology Building offers a variety of formal and informal gathering spaces that are associated with individual laboratories (such as the tea rooms). Furthermore one lounge on every floor is a two-story high community space. Goody Clancy expressed the difference through that increased height and a projection of the facade out into the space of the campus (figure 14).

Those configurations that are consistent with a distributed network model of connectivity exhibit sufficient redundancy in the system that multiple means of access and resources are available. In terms of space planning, this can mean that the location of something like a lounge, a balcony, or a reading room needs to be positioned in the circulation system in such a way that it has multiple means of access. For example, if located on a cul-de-sac, a sharable space is more easily territorialized by their nearest neighbor, removing it from the community network.

Figure 15 The visual porosity of rooms surrounding the stairs at Koch



6. a. Research:

a principle strategy for increasing individual and organizational value is forming connections outside one's primary circle of relationships and contexts.

The sociological foundation of network theory derives from a 1973 essay by Mark S. Granovetter. In "The Strength of Weak Ties," Granovetter traces how "weak ties" formed by casual acquaintances (outside one's primary circle of co-workers, family or friends) lead to a clear advantage in finding the job they seek. The importance of generating "weak ties" and interacting with multiple contexts has formed the basis of considerable further research. Ronald Burt (1992) finds that when conversations occur between people from different social networks, even irregular contact can bridge the gaps he refers to as *structural holes*. Structural holes are a result of being isolated within one's own context.

Burt theorizes that organizational value increases by identifying and crossing "structural holes" in one's organization or industry. Doing so makes one more competitive and fosters a better understanding of the social structure of competition, or what he calls "the *social capital of structural holes*".

If social capital is an advantage that accrues from "connections" beyond one's primary group or context, site and building design have many tools for increasing organizational value. More than a few are evident in Goody Clancy's design of the Koch Biology Building.

6. b. Design Strategies:

The spatial connectivity in a building inscribes patterns of social interaction and movement. Architecture also models connections between people and their surrounding, non-human environment. By responding to more than one site context, the inhabitants visualize bridging "structural holes."

Several bold examples of cross-laboratory connectivity in the Koch Building were previously mentioned in this chapter. Other gestures are less noticeable unless one spends time in the building. For example, the location of men's and women's restrooms varies from floor to floor.

Given that environmental behavior is slightly out of awareness and habituated, amenities that is less predictable (but equally available) break the "auto-pilot" routine. In the process, it is necessary to walk a different way, take another stair, and sometimes apologize.

The bathroom routine may seem trivial in the overall dance in a university research facility. Yet, the subtle features of architecture accumulate; and they animate the inward apprehension of time and place, as well as one's awareness of other people and other contexts.

Goody Clancy posits a shift in awareness through the architectural expression of the community lounges. As seen on the facade, in plan, and section, these two-storey, all-community lounges jut away from the tightly held order. Extending a community resource by a few feet in height and out into the plaza below, inhabitants can see the Charles River while reading in the lounge.

Figure 16 Drawing showing the expression of the community lounges on the exterior

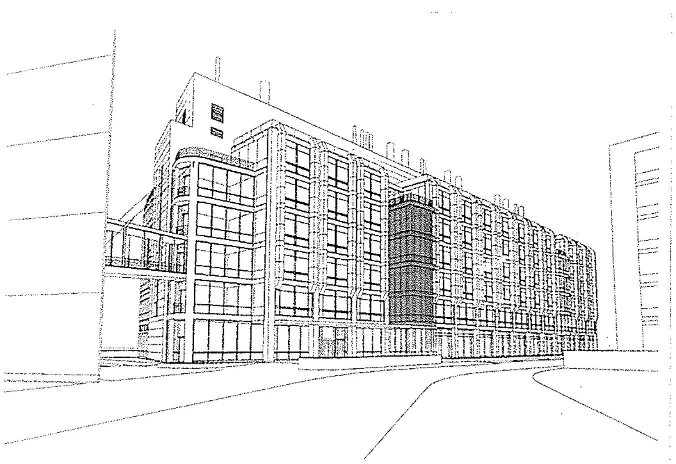


Figure 17 The view to the exterior a Tea Room in Koch

Being able to catch a glimpse of the river, the light, and Boston skyline beyond, the architecture integrates the original grid of campus (Massachusetts Avenue and the river), and the grid of Main Street's growing bio-medical industry. Goody Clancy's Koch Biology Building demonstrates an architectural manifestation of bridging a structural hole (figures 15, 16, and 17).

Conclusion

In this chapter, I construct (retrospectively) a body of evidentiary arguments linked to the design of the Koch Biology Building. Needless to say, these are my own, and not those of the architects. They are used to demonstrate translations between research and practice. In this case they have resulted in the design of an extraordinary zone of connectivity from the most carefully controlled to the most accessible space, and every point in between.

The best evidence, however, can be found in the way that this design contributes to the forward movement of the science it houses. During an interview last summer, I pressed Professor Richard Hynes, (a member of the original Biology Building Committee), about whether bumping into other researchers with whom one does not work is actually critical to the growth of science. Isn't connecting on-line, at conferences and through the literature more important? Hynes responded,

RH: I don't know if everyone else thinks this way—I remember the architects were surprised by how adamant we were. But we were right.

JH: Is it because of how inter-disciplinary Biology has become?

RH: Yes, I think so. It is a very fast-moving science. So, being plugged into the grapevine is very important...There is a lot of scientific gossip. I would have thought that [other sciences] did it as well. But I did have an argument with a Dean, when I was Department Head, who was complaining that I was always seeking more money for our courses, for re-tooling our courses. So, I asked him when they start teaching the undergraduates Post World War II Physics. He said we don't get to that until graduate school. Well, I said, nothing much that we teach precedes World War II. Everything is rapidly moving and everything changes every year—even at the undergraduate level.

So that may be another reflection of the fact that what we do now is not what we did a year or two ago. The way in which we do things—and this is why MIT is such a good place—is that it is so close to the grapevine, both without and within.

Notes

1. Since the mid-1960s there exists a rich record of research about the effect of places on people (such as post-occupancy evaluation or POEs), and the application of this and other environment-behavior research into design decisions. In 1968, the Environmental Design Research Association (EDRA) was founded by design professionals, social scientists, students, educators, and facility managers for the advancement and dissemination of environmental design research from its several thousand members who engage in discipline-crossing design research within and between public and private sectors, and from within universities, consulting practice and design firms. For more information visit http://www.edra.org. This website has links to edra-affiliated scholarly journals, book series about behavior-based architectural research, and several PhD programs.

2. See D. Kirk Hamilton, "Four Levels of Evidence-Based Practice," in *AIA Journal of Architecture* (December 2004).

3. One that emphasizes digital technology: J. Novitsky, "Changing the Face of Practice with Digital Technologies," in *Architectural Record* (February 25, 2004). For an approach that focuses on business models from other industries see a good summary of the work of Susan Harris and Kyle Davy of the Advanced Management Institute for Architecture and Engineering, "Architects Play Catch-up in the Business World," in *Seattle Daily Journal* (November 20, 2003).

4. This description reflects conversations between the author and the principals of MK Think, San Francisco.

5. My evidence about the origins of net-to-gross is anecdotal. However, the typical use as a ratio of rentable space, such as in the case of commercial office space, is considered efficient when it occupies at least 80% of the gross square footage, so that the least amount of capital is devoted to non-rentable spaces like corridors, bathrooms, storage, and mechanical rooms.

6. In another sense, the tools we need now are just like net-to gross—easily used by architects and non-architects, like an analog tool, that works directly, manually.

7. I had contracts with Engelbrecht Griffin Architects (1988-1998), and I was the first recipient of the Goody Clancy Summer Faculty Fellowship (2004).

8. Discovered by Napoleon's troops in 1799, near the seaside town of Rosetta in lower Egypt, a British physicist and French Egyptologist collaborated to decipher the hieroglyphic and demotic texts by comparing them with the Greek opening. There are many books about the stone which resides in the British Museum as well as the riddles of deciphering it.

9, The campus planning attitude that stresses the connectivity of campus buildings (over their object status) and typically wrap rectilinear buildings around interior courtyards were part of an MIT tradition that may have ended with the retirement of an era of planning directed by Robert Simha. Neither of these MIT versions of campus urbanism are present in the Stata Center designed by Frank O. Gehry and Associates.

10. See Jamie Horwitz and Michael Underhill, *Iowa State's Memorial Union: An Architectural and Social Evaluation of a Campus Treasure* (Ames, Ia.: Design Research Institute, Iowa State University, 1989).

11. Jackson's quote continues:
"It suffers, in other words, from no landscaping, no beautification, no overt behavioral design. In the Medieval village this vernacular space was where we grazed our domestic livestock, where we gathered herbs and plants, where we went for kindling and gravel, and where we played games and celebrated holidays. The use and abuse of the common was almost always a source of contention and ad hoc rules, but the use of it, the right to use it, was an essential part of citizenship, and to be excluded from it was the equivalent of ostracization and exile."

12. John Zeisel, *Sociology and Architectural Design* (New York, N.Y.: Russell Sage Foundation, New York, 1975), 25.

13. 'Behavioral traces' comprise a method of collecting data about how people use places that is explained in John Zeisel, *Inquiry by Design* and *Sociology and Architectural Design*.

14. Paul Baran, *On Distributed Communications,* RAND Corporation memorandum RM-3420-PR (August 1964).

15. Peter Galison, "War Against the Center," in *Architecture and the Sciences,* Antoine Picon and Alessandra Ponte, eds., (New York, N.Y.: Princeton Architectural Press, 2003), 220.

16. Albert-Laszlo Barabasi, *Linked: The New Science of Networks* (Cambridge, Mass: Perseus, 2002), 144.

17. At the invitation of Mark Engelbrecht and Engelbrecht Griffin Architects (EGA), I studied full-service retirement communities that were designed by EGA and occupied for at least ten years. Initially, I focused on Friendship Village of Columbus (FVC) with its three hundred plus independent living apartments, health care and associated amenities; FVC was a standard upscale CCRC within efficiency standards. A large suburban tract and an unusual degree of freedom in the design development Engelbrecht was able to execute a design experiment that broke many of the rules of thumb and standard walking distances for a project of this type. And he wanted me to evaluate it.

Engelbrecht thought that his previous designs of CCRCs for Weitz had overly differentiated the components of the CCRC program, creating a building that neglected the intermediate spaces needed for socializing, allowing for the ebb and flow that, he hypothesized, could be evoked by a clustered plan. Engelbrecht wanted the energy and activity associated with the entry gathering spaces to be "threaded throughout the village-like structure." His concept was to divide the building into five residential wings, each wing wrapping short segments around a multi-access courtyard with rest areas at 90 degree turns. Keeping the main lounges at the entry, Engelbrecht located "neighborhood lounges" on the ground floor of each residential wing. The five Wing Lounges have partial glass doors, a rear access to street parking, a full kitchen and restrooms, and can seat up to twenty in a comfortable, living/dining room style room.

By conducting focus group interviews, surveys, and living at FVC, I learned that the wings are not perceived as neighborhoods. No one uses a Wing Lounge for casual socializing or because it is near their apartment. Wing lounges are booked, sometimes a year in advance, for family parties, bridge tournaments, and church groups for residents who remain mindful of making plans, and appreciate bringing guests coming to the Wing Lounges directly from an affiliated entry in the parking lot. Residents with less organized social lives use the central lounges and the charge that comes from being by the entry, and none of them worry very much about getting lost in the exceptionally complex and elongated configuration.

Initial data revealed not only contradictions with the architect's desired "neighborhood strategy" but also a long waiting list for vacancies, in part because residents of FVC were living much longer than expected (actuarial tables had to be revised) amidst an extraordinary conviviality (more than 40 different resident committees kept the management and the Ohio legislature, busy) and I began to study CCRC's that are similar in every way other than the circulation and gathering places. CCRC's with split commons, and centralized commons showed statistically significant less satisfaction with their social life, social spaces, and observably less presence in the hallways, longevity, or the vitality of activities with social groups outside the retirement community. Reflecting on FVC through network theory made me see that because residents use all the different lounges, and residents and guests can enter from the parking lot to wing lounges, they rival the main entry in terms of their connectivity. While the building appears to be a decentralized network in plan, such a model would remain dependent on the hierarchical center of the main entry. Here the entry at the wings and their gathering spaces create a redundancy of access and control, thus competing with the center.

It is worth noting that the "pioneers" (the originally residents and long-lived leadership) of FVC succeeded in taking a bill through the Ohio legislature that would guarantee all residents of life-care community's access to the financial records of their management, in this case, Life Care Services.

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A Comprehensive Approach to Teaching Structures Using Multimedia

Shahin Vassigh
University at Buffalo/SUNY

Introduction

The project *A Comprehensive Approach to Teaching Structures Using Multimedia* was the outcome of a collaboration of an inter-institutional, multi-disciplinary team from the University at Buffalo, State University of New York; University of Oregon and University of Utah. The project aim was to create an environment for teaching and learning structures that facilitates the comprehension of fundamental principles, practical aspects of structural design, and the creative possibilities of applied structure within the built environment. The project began by a seed grant from the University at Buffalo in 1999 and was funded by the U.S. Department of Education, Fund for the Improvement of Postsecondary Education (FIPSE) from 2001 to 2004. The faculty team project included: Shahin Vassigh and Dr. Scott Danford from University at Buffalo, the State University of New York; Patrick Tripeny from University of Utah; Ronald Shaeffer from Florida A&M; Christine Theodoropoulos from University of Oregon; and Edward Allen.

Motivation

The teaching of structures (the analysis, behavior, and design of structural systems) within academic architecture programs faces a fundamental problem - understanding structures is central to the education of the architect, but the content "content" (theory and pedagogy) and "delivery systems" (teaching methods) currently in use are distinctly inappropriate for the vast majority of architecture students. Architecture faculty and students struggle with a traditional engineering-based approach to structures instruction, which is increasingly proving to be ineffective in the classroom.

Architectural educational preparedness has been examined extensively over the last decade, with most almost universal agreement that the nation's universities are producing graduates who are technically unprepared for the professional practice of architecture. Numerous analysts and writers have documented this problem as a national educational weakness, and identified it as a threat to the architecture profession.

The practice of architecture requires an applied understanding of structures, construction, and technology. Yet as early as 1989 P/A Magazine surveyed its readers on the quality of architectural education. Eighty-one percent of those who responded agreed that architecture schools do not adequately prepare students for practice. "Seventy-five percent of those respondents who identified themselves as faculty and students agreed that education for the world of practice was inadequate."[1] A 1994 national study by the National Institute for Architectural Education recognized a clear and "widening gap between theoretical and practical knowledge and the conflicting objectives of academic preparation and professional practice."[2] The study also concluded that recent graduates lack of skills pose a serious problem which damages the practice of architecture and its professional influence. A 1995 study by the National Academy of Sciences National Research Council reached similar conclusions, noting that "recent [architecture] graduates possess a good understanding of broad design concepts and the design process, but lack knowledge of the practical aspects of construction and building technology."[3]

Poor technical preparation and the failure to adequately educate architecture students in structures is the result of three basic problems. First, the structures curriculum, teaching methods, and instructional tools are borrowed wholesale from engineering programs with little modification. Instruction is therefore highly quantitative, communicating even basic concepts using a high-level mathematics nomenclature. Architecture students do not have neither the background, disposition, nor time to master the mathematics skills required to understand or utilize a system based on highly abstract mathematical models and therefore, quickly become uninterested, frustrated or intimidated by the structures curriculum. The consequence is that many architecture students fail to master the basics of structural theory, much less the more demanding aspects of applied structural design and innovation.

Second, the applied-engineering approaches to teaching structures and building technology uses a methodology which consecutively subdivides and dismalness a structure into extremely small subcomponents, focusing on a particular element, detaching it from all other connected structural members, and then reducing it to a notation system of structural symbols, mathematical formulae and annotations. The engineering approach places an emphasis on the quantitative analysis and performance of structural sub-assemblies. Structures are therefore studied in the abstract using an arcane system of symbolic notation. Structures instruction delivered in this way almost never attempts to connect detailed analysis back to broader building design and construction principles.

Lastly, in most architecture programs the structures curriculum is taught separately from the remainder of the architecture program. Structures instruction is rarely, if ever, fully integrated into the broader architecture curriculum. In particular, creative structural design and application is left out of most architecture design studio courses. Architecture design studios are where architecture students interact one-on-one with faculty to solve design problems and are the central means by which students learn to apply concepts learned elsewhere in the program. Design studios provide the means for highly directed, interactive instruction and the opportunity for students to integrate, demonstrate, and apply the cumulative concepts and issues they study throughout their learning tenure. By excluding or limiting issues of structure within the design studio, students miss primary opportunities to reinforce structures concepts, the importance of structure as a design element (and opportunity) is also overlooked; meaning new opportunities for students to develop innovative and expressive design using innovative structural design is also lost.

Structures in many architecture programs is therefore treated as the unwanted stepchild of the curriculum—viewed as difficult to teach by faculty and a complicated and uninteresting requirement for graduation by students. Unfortunately, these conditions have critical consequences for the professional practice of architecture. First, failing to adequately prepare architecture graduates in structural design and application creates unnecessary economic costs. Professional architecture firms are forced to invest in the technical training required to properly educate practicing architects in the basics of structural design. P/A magazine, writing in 1995 on the failure of architecture programs to adequately prepare new graduates for practice, noted that "many architects now take it for granted that they will have to train them [new graduates] to be valuable employees or they refuse to hire new grads altogether."[4]

Complex construction and advanced building design require an understanding of structures and construction technology, so that under-preparing architecture graduates may pose a significant risk to the quality of the built environment and a clear and present danger to the professional practice of architecture. Modern building design and construction is highly interdisciplinary, requiring a clear understanding of applied structures in order to effectively manage the teams of technical personnel required to complete complex building and design projects. Architecture students, for the most part, leave the academy poorly prepared to communicate and work with engineers. Mario Salvadori[5], Heino Engel[6], the Building Art Forum,[7] and Gary Black[8] have written extensively on the growing gap between architecture and engineering.

With shrinking technical capability important decisions regarding the design of the built environment are increasingly *not* made by architects, meaning that architects have increasingly less control and influence over the design of the built environment. By effectively limiting the role of the architect within the design and construction process, the profession risks being marginalized, increasingly reduced to addressing only aesthetic issues of building design and urban form.

Elizabeth Padjen, commenting on the architect's loss of professional "turf," has said that "the practice of design was a...process in which the architect was in charge of the whole ball of wax, peeling off pieces to give to consultants and contractors. Now...the architect's role is only one of many small bits assembled along the way by any number of construction coordinators."[9]

Improving Structures Education Using Advanced Media

Improving the technical preparedness of architecture graduates has important ramifications for the practice of architecture and society as a whole. Large scale reform of architecture curricula nationally is and will be a complex, ongoing, and difficult debate and effort. However, improving structures teaching tools could have immediate impacts on improving architectural educational quality.

The project described is an alternative structures teaching/learning tool that seeks to better meet the architecture student's needs and capabilities and improve the understanding and application of basic and intermediate structural engineering and technology principles. The project harnesses the capabilities of advanced multi-media graphics and Internet based communications technologies to provide a powerful set of tools to improve the delivery of structures instruction.

The three broad objectives of this project were to first, demonstrate that new multi-media digital technologies could be utilized to develop instructional tools to study structures in ways that not only better meets the needs of architecture students, but demonstrably improves their understanding and mastery of the subject. Based on an alternative pedagogy, this project aimed to show that quantitative scientific methods can be effectively integrated with qualitative and conceptual methods, grounded both in the practical aspects of building design. The second objective is to develop and implement an evaluation procedure and performance indicators that measures changes in student performance and the application of learned structures concepts in their design process. The third objective aimed at showing that the project's outcome can be easily distributed and used, and that the same positive results can be attained across many programs—that the results were not unique to a single instructor and can therefore be used in any architecture program.

Proposed Strategy: Interactive Structures Software

The starting point for improving the technical education of the architect begins with the recognition that if architecture students are to effectively learn and apply structural analysis and design, teaching methods and tools must respond to their needs, capabilities, and perspective. Therefore, the design of the project is based on a pedagogy based on the following principles:

- Teaching structures should facilitate comprehension of fundamental principles of the practical aspects of structural design as well as the creative possibilities of applied structure within the built environment. The communication of basic theory and principles should focus on reinforcing and demonstrating principles of application.

- Particularly for architecture students, the instruction of structures should be visually and spatially grounded, so that it is understood as an integral part of the conceptual and theoretical aspects of design.

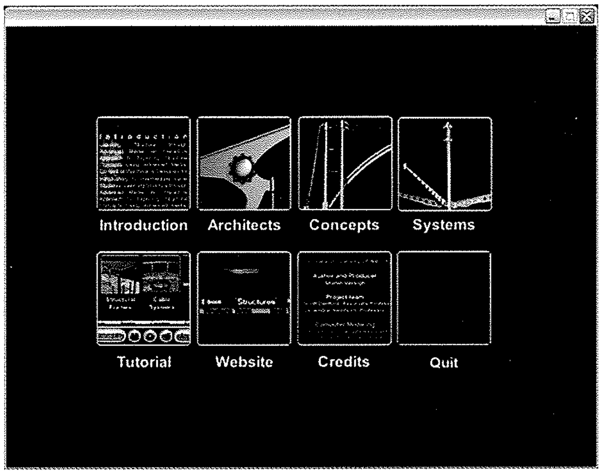


Image 1 Menu options for the ISS

- Teaching tools should make the instructor more effective in the classroom, make the student a more efficient learner, and make student-faculty interaction as effective and efficient as possible.

- Instruction should aim at increasing student interest in structural design, particularly as a life long learning skill. Since architecture is a continuous learning process, creating an interest in structures can positively affect a student's predisposition to further explore structures as a practicing professional. Effective education should not be uniquely dependent upon a single instructor or a single discipline. The educational materials should be developed as interdisciplinary ventures among architects, engineers, and others.

The project is composed of three components: the Interactive Structures Software "ISS"; the instructional support center "Structures Learning Center", and student performance evaluation tools.

1. Interactive Structures Software ("ISS")

The ISS is a multimedia program that uses a wide range of digital and graphic technology including computer generated 3D models, interactive images, full motion video, audio narration, and hypertext functionality to improve the teaching and learning of structural concepts. The ISS divides the study of structures into three concept areas. These include Basic Concepts, Structural Systems and Architects modules.

Each module is divided into eight sections. There is an average of 20-30 animations in conjunction with fully graphical illustrations and images in each module that explain general structural analysis, concepts, definitions, working principles and architectural design issues. The Basic Concepts module includes statics, loads, structural materials, mechanics of materials, connections, lateral supports, foundations and structure & form.

The Structural Systems module includes an overview section, trusses, columns, beams, cables, arches, frames, and surface spanning elements. The organization of Basic Concepts and Structural Systems are similar in that all the presented principles are demonstrated with the use of highly detailed and realistic 3-D computer generated models and animations. Each module is designed to overcome the limitations of two-dimensional abstract representations of structural behavior in the traditional textbooks by providing a relatively realistic context.

Image 2 Basic Concepts menu

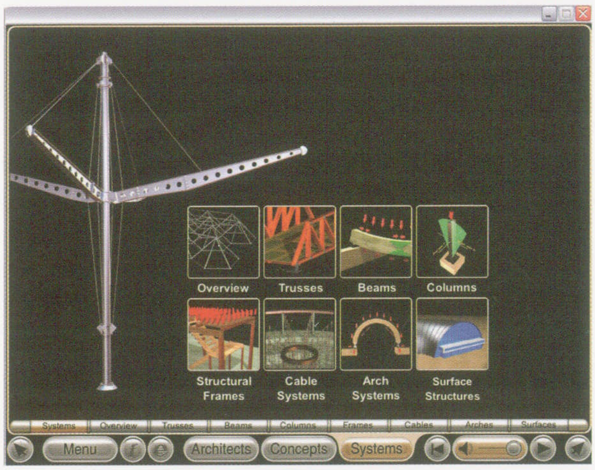
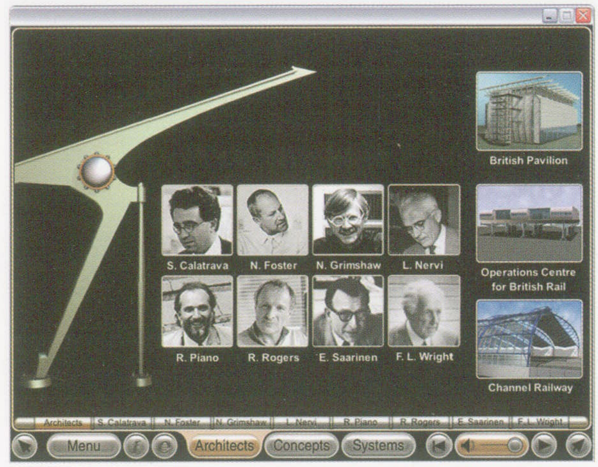


Image 4 Structural Systems menu



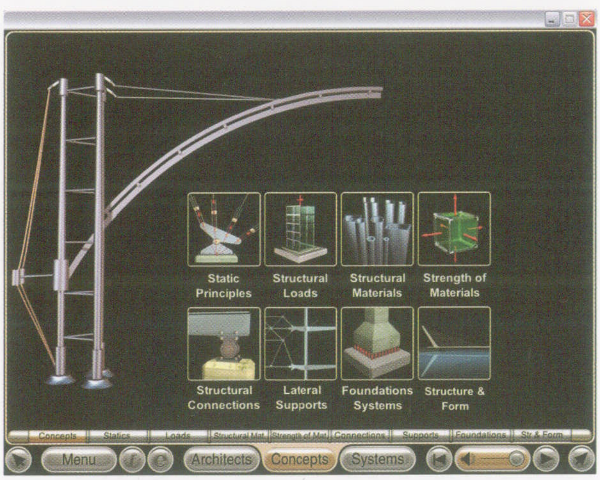


Image 3 a Sample screen from the Basic Concepts menu introducing typical structural connections

Both of these modules include numerical interactive example problems and quizzes. The interactive examples are also highly visual and allow the user to interact with the graphics to alter variables in order to create new problems and solutions. Each quiz is presented in a graphical interface with a 30 second timer and a series of five questions that are randomly selected from a large data bank. Each question that is answered correctly is rewarded with a score and the unveiling of a structure to the right of the screen.

The Architects module features eight prominent architects with three building structures selected from each architect's work for purposes of analysis. This module has a different organization than the Basic Concepts and Structural Systems modules. Once the user selects an architect and a building, the general information regarding the location, function and major structural systems of the structure are displayed. The user is then presented with five windows that interact with each other. The four windows located on the right side of the screen contain lessons on the structural function and construction details of the building. The fifth window on the left side of the screen functions as a guide and provides the exact location on the structure for the details being explored. Every time the cursor enters one of the four windows on the right side of the screen, the fifth window on the left side of the screen automatically adjusts to the proper scene. This provides an immediate context grounding the structural principles in a virtual building environment.

Written using multimedia-authoring software, the ISS is available on a 3 volume CD-ROM or a single DVD in both PC and MAC formats. Each CD or DVD includes a printable version of the entire text. ISS is published and distributed by John Wiley and Sons, Inc.

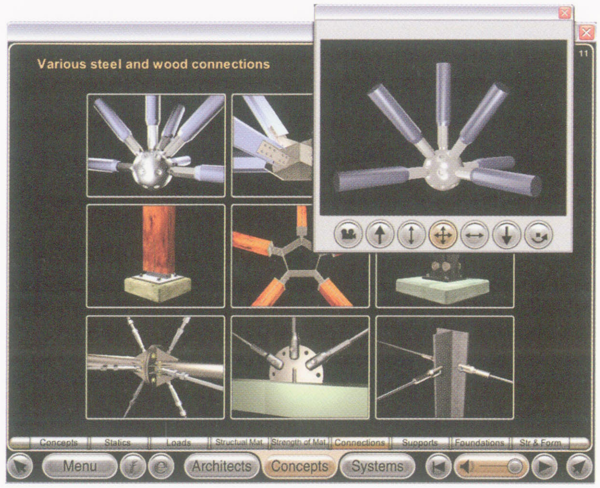


Image 5 Architects menu

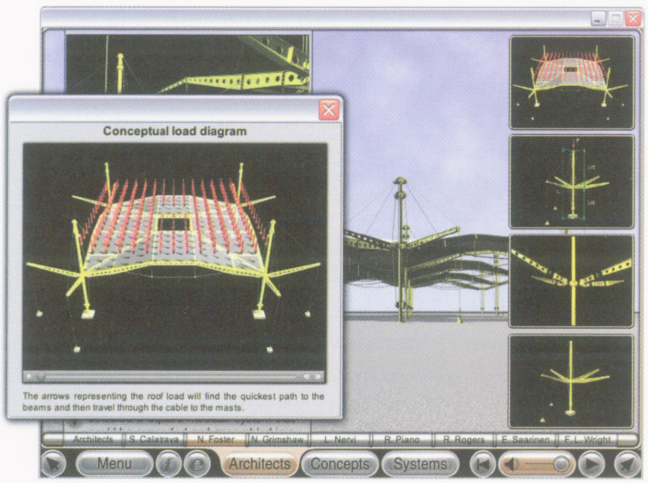


Image 6 Sample screen from the Architects menu showing the analysis of a cable supported structure

2. Instructional Support Center Website: "Structures Learning Center"

The second component of the project is the instructional support website or the *Structures Learning Center*. The objective of the website is to provide additional resources to students using the ISS. The website is relatively comprehensive and is composed of terms, concepts, resources, student performance evaluation tools, instructional support relevant to structural analysis and design, and demonstrations, purchase options, and technical support related to the ISS.

The website is organized into three main components that include: *Structures, Resources, and ISS*. The *Structures* component is organized into sections similar to the ISS and contains a glossary of terms, information on basic structural concepts and systems, and an interactive quiz and a puzzle section for students' self performance evaluation. In addition, this section contains a complete series of tables providing general guidelines for span lengths, load capacities, size, spacing and depth ratios, and various interactive animations that visually demonstrate the structural behavior of the system. The purpose of the tables is to provide architecture students a general range of rules that can be applied in the design-studio setting. There is also a section of quizzes, games, and puzzles related to structures.

The *Resources* section contains an extensive list of books, videos, CD-ROMs, and websites relevant to structures. Currently, the list contains roughly 200 books, 100 web sites, and close to 20 video/CD-ROM sources—making it one of the most comprehensive list of structures resources on the web.

The ISS section contains demonstrations and purchase options. The software can be ordered, and eventually upgraded from the website. On the main page, there is also a list of contacts that are available to augment, support, improve, and answer questions on the use of the ISS, the web page, or the structural content itself. Questions can be posted on a message board and will be added to a searchable database of Frequently Asked Questions (FAQ's). Comments from users will be solicited and used to continuously improve and refine the educational program and instructional materials.

To expand use of the website it is also for visually impaired users. This feature allows the users to customize the screen based on their vision. By pressing the "customize" icon the user can change the font size and color, and adjust the screen background color. In addition, the website is equipped with Breadcrumbs. Breadcrumbs provide a trail of text above each page explaining system operation and the navigation.

3. Student Performance and Evaluation

The objectives of the project evaluation was to measure whether the use of ISS improved student test scores, application of structures principles to architectural design work, and whether it changed student attitudes toward structures. The primary target population for the project evaluation was the undergraduate sophomores and juniors taking two required structures course and two design studios at University of Buffalo.

In order to establish that the project results were not unique to a single instructor or institution, another group of students participating in a similar program were identified at The University of Oregon and took part in the project. The evaluation of the gathered data from University of Buffalo is completed and presented here. However, the result of the evaluation at the University of Oregon is in progress and has not been concluded at this time.

Evaluation Procedure

Prior to implementation and testing, student SAT scores and were obtained. This data was used to insure consistent student groups and compensate for individual variations in test results. In addition to design and development of the tests, projects and survey questions, evaluative standards and performance indicators were established to provide accurate, consistent, quantitative measures of student performance.

Students taking two structures courses, introductory structures 1 and intermediate structures 2, were divided into two groups—a *control group* which received traditional structures instruction *not* using the (ISS), and an *experimental group* which received instruction using the ISS. The Structures 1 experimental course used the ISS heavily as its content covered the entire introductory course requirement. The Structures 2 experimental course used the ISS less intensely as the latter part of the course was design oriented.

Throughout the evaluation cycle, each group was monitored closely.[10] All the course work such as exams, assignments, and class projects was graded and recorded according to the evaluation program grading criteria. Once the implementation of evaluation program was completed, the data was analyzed with various statistical programs. The project team selected T-test results to interpret the student score data and grades. The evaluation program also measured attitudes toward the structures by delivering an Attitude Survey which questioned basic attitudes towards structures, how knowledge of the subject is utilized within the design process, and gauged basic interest level in the subject at the beginning and end of each structures course. The survey data was analyzed by using the Mann-Whitney test.

The complete project evaluation, individual survey questions, and statistical analysis of student of student performance and responses are posted at the project's website www.learningstructures.org. The following is a summary of findings.

Structures 1 Course: T-Test Results

The results of t-test comparing the performance of students in the control and experimental group in the Structures 1 course showed significantly positive results for all the tests. Both experimental and control group were given three identical tests. Comparing three test grades from each course showed an increased improvement in the student performance as their exposure to the ISS increased. This was evidenced by an increase of 10 points in the class mean grade for the first two exams with a significance level of 0.049 and an increase of 18.5 in the class mean grade for the final test with significance level of 0.005.

In order to further analyze the students test scores, and examine the project's team hypothesis that the ISS would help the students with lower SAT scores and weaker mathematics skills at a greater extent, a second t-test was performed. This test compared the test scores of the students in control and experimental group in two separate categories of high SAT mathematics performers, and low SAT mathematic performers.

The t-test results showed that although both groups benefited from using the ISS in the experimental course, the low SAT math performers were impacted the most. The mean grade for the final exam of the students with lower SAT mathematics score increased by 15.5 points with significance level of 000. This finding approved the initial hypothesis of the project team.

Structures 1 Course: Mann-Whitney Test Results

The evaluation program measured attitudes toward the structures subject by conducting *Attitude Surveys* that questioned the level of student interest, effectiveness of the course, impact of digital media in learning, and the students' ability or desire to apply their knowledge of the subject in the design process. Each group was given two sets of survey questions, a pre-survey set at the beginning of the course and a post-survey at the completion of the course.

The Mann-Whitney test was used to compare the pre-survey and post-survey data from the control and experimental group. The analysis of this data showed a significant improvement in the students' attitude towards structures in the experimental course, with 15 out of 27 post-survey questions showing a statically significant improvement. For example, when students were asked if they agreed that multimedia digital technology can enhance learning concepts related to structures, the post-survey course results in the experimental course showed a strong improvement in the students' perception of digital media, with a 34 percent increase in students who strongly agreed with the statement at significance level of 0.000. When students were asked if they felt that architectural education can benefit through gaining a better understanding of structural concepts, in the post-survey of the experimental course, the students' response changed by a third from ambivalence to positive at a confidence level of 0.023

When asked if they felt competent in applying basic structural principles to their design work, 22 percent more of the students in the experimental group agreed strongly while the ambivalent and disagreed answers dropped by 18.5 percent. This is was at a significance level of 0.038. When asked if the use of visual graphics makes understanding structural concepts less complicated, the post-survey of the experimental course showed considerable improvement. Most dramatic was the 26 percent increase in students' response who strongly agreed with this statement. The number of ambivalent answers dropped to half in favor of utilizing visual graphics to teach. And finally in response to if architectural education can benefit through gaining a better understanding of structural concepts, the post-surveys of experimental course showed 13 percent increase in strongly agreed answers, and a drop of 25 percent in the ambivalent and negative responses. This was at a significance level of 0.023.

Structures 2 Course: T-Test Results

In structures 2, the students were given two tests. The results of t-test comparing the performance of students in the control and experimental group in the structures 2 course showed an overall improvement in both tests. The class mean grade for the first test in the experimental group improved by 10.4 points with a significance of 0.000. The result of the second test did not show a statistically significant improvement in the experimental group performance. This could be explained by the content of second part of the course, which concentrated on sizing structural members and did not involve using the ISS.

Structures 2 course: Mann-Whitney Test Results

In general the change in student response to the survey questions were less drastic than Structure 1 course. Although the attitudes toward the structures course still improved with exposure to ISS in the experimental group, the results were only statistically significant in a few questions. For example, when students were asked whether they find the methods of teaching material related to structures in the architecture curriculum educational and appropriate, the post-survey in control group showed a 31 percent increase in the positive answers with a significance level of 0.003, indicating that the ISS offers a more appropriate teaching method. When asked if an understanding of structural concepts makes them more employable, there was an increase of 22.5 percent of strongly agreed and a 25 percent increase in agreed responses in post-survey of the experimental group.

The less keen responses in the structures 2 courses could be related to the fact that by the time the students took the post-survey in Structures 2 experimental course, they were answering the same survey questions for the fourth time, and have been using the ISS for two consecutive semesters, thus being less enthusiastic in their answers.

Studio Evaluations

The evaluation of the students' application of structures principles to their design work was done in each studio immediately following each of the two structures courses. This was based on a self evaluation by the students and an objective assessment of students design work by an independent reviewer from the University of Utah.

The results of the self evaluation and expert reviewer did not show any significant improvement in design work in the studio immediately following Structures 1 course. This results are not discouraging since the content of Structures 1 is introductory, and is not application oriented.

This trend changed in the studio immediately following the Structures 2 course, indicating an improvement in both categories of assessment. For example, when students were asked to what extent the consideration of structural issues was a part of their personal initiative, the number of students responding "to a great extent" increased at a significance level of 0.01 from pre to post self evaluation. In answering to what extend they thought about selecting a particular structural system, again the number of "to a great extent" increased at a significance level of 0.049 from pre- to post self evaluations.

The expert reviewer looked at ranking five different categories in students' design work.[11] The results of this assessment followed the same pattern. There was an improvement in all categories however, the students consideration of "lateral supports" in their design work showed a statically significant improvement in studio following Structures 2.

Closing Remarks

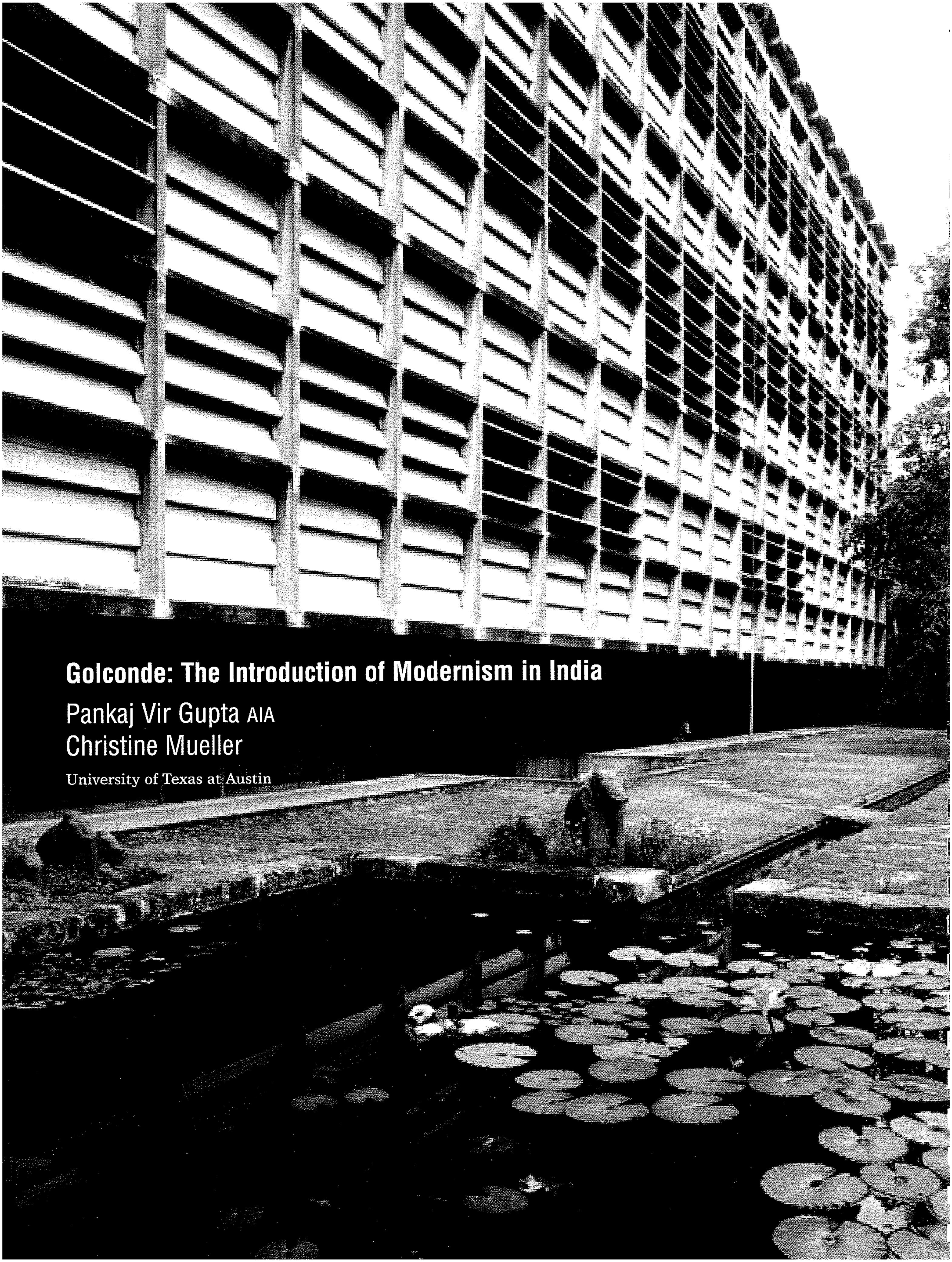
The problems with the current approach to teaching structures are rooted in the use of an engineering based model, which is founded on abstraction and reduction. Architects think, learn, and approach the design of the built environment differently than engineers. Unfortunately, the standard engineering-based approach employed to teach structures does not address the thinking, strengths, and weaknesses of architecture students. Clearly, most architecture students do not have a strong mathematical background, but they do possess a strong facility for and training in three-dimensional visualization and can quickly absorb information through this medium.

Therefore, any approach, which is used to teach architecture students effectively and to promote an intuitive understanding of the subject, needs to be sensitive to these issues.

The project described above was built on addressing these issues. The evaluation results of the project's first round of implementation are extremely encouraging, and confirm the central underlying principle for the development of the project, which was utilizing visual techniques to improve student performance. The project findings also point to the great potential of digital technology in other areas of architecture education such as lighting/electrical, plumbing, heating/cooling/ventilation, and construction. Since architects are well trained in digital modeling and providing visualization tools, it is a natural step for architecture education to benefit from this advantage.

Notes

1. Thomas Fisher, "Reader Poll: Education," *Progressive Architecture* (1989): 15.
2. See National Institute for Architectural Education, "Architectural Education and the Built Future" (1994).
3. Commission on Engineering and Technical Systems, "Education of Architects and Engineers for Careers in facility Design & Construction," in *The National Academies Press* (1995), 30–31, 51.
4. Thomas Fisher, "Can This Profession be Saved?"*Progressive Architecture* (Septembe, 1995): 46.
5. See Mario Salvadori, *Structures in Architecture: The Building of Buildings* (Englewood Cliffs, N.J.: Prentice Hall Inc., 1986).
6. See Heino Engel, *Structures Systems*, Deutsche Verlags-Anstalt GmbH Stuttgart, 1967.
7. See Building Art Forum Publications, *Bridging the Gap: Rethinking the Relationship of Architect and Engineer* (New York, N.Y.: Van Nostrand Reinhold, 1998).
8. See Gary Black & Steffen Duff, "A Model for Teaching Structures," in *Journal of Architectural Education* (September 1995).
9. Fisher, "Can this profession be saved?"47.
10. The average number of students (or sample size) in each course was 75.
11. These categories looked at ranking the students' projects in the selection of overall structural systems; systems resisting gravity forces; systems resisting lateral forces; materials; and the compatibility of the structure with the architectural design scheme.



Golconde: The Introduction of Modernism in India

Pankaj Vir Gupta AIA
Christine Mueller
University of Texas at Austin

As contemporary architectural practice has sought to cope with the demands of an increasingly global society, architects are confronting the dilemma of proposing design solutions in unfamiliar cultural and geographic contexts. All too often, the international nature of contemporary practice compels an accelerated schedule of client meetings, site visits, and design proposals, all on unfamiliar cultural and geographic terrain. The results of this type of engagement seldom result in an architecture capable of assimilating the nuances of site, local identity, and technology.

Our research has focused on an exemplary work of early modernist architecture in India, designed by two pioneers of the modernist movement. Working within a cross-cultural platform, they built one of the earliest works of sustainable modern architecture in the world. It predates the more renowned, modernist essays by Le Corbusier in Chandigarh (1951–64) and Ahmedabad (1952–56), and pioneers the use of reinforced concrete construction in India. Completed in 1945, the building—a dormitory for a spiritual community—espouses the virtue of radical economy and uncompromising construction standards. It proposes a mode of architectural practice where issues of technology and environment dictate the conception and tenor of the entire design process.

HISTORY

> *Sri Aurobindo Ghosh intended to build in his very active and growing Ashram a truly up-to-date modern dormitory for his disciples. St. Hilaire had been writing to me about the project for some time. He sent me photographs of the Pondicherry architecture, eighteenth century French colonial, with high-ceilinged dark rooms behind colonnades and roofed terraces. These I had criticized as unsuitable in this day and age of advanced techniques and an absence of formal elegance. This point of view and an unexplainable confidence in me from Sri Aurobindo brought about his request for my photograph upon the receipt of which he apparently formed a judgment of my character and sent me a considerable sum of money for expenses to cover the transportation of my wife, son and myself to India.*[1]

Sri Aurobindo (1872-1950) was born into a prominent family in Calcutta, the first capital of British-ruled India. At the age of seven, he was sent to England, where he studied at St. Paul's School in London, and at King's College in Cambridge. Returning to India in 1893, he became an active participant in the Indian freedom struggle against British rule. In 1908, the British Government imprisoned Sri Aurobindo for his role in anti-government activities. His year-long incarceration provoked a series of spiritual experiences, causing a sudden devotion to an evolving spiritual mission. In 1910, he decided to leave the territory of British India and settled in the French colony of Pondicherry on the south-eastern coast of India.

In 1926, Sri Aurobindo established a spiritual community with his disciple Mirra Alfassa (1878-1973), known by devotees as simply "the Mother". Mirra Alfassa was a French citizen of Egyptian-Turkish parentage. Together, they developed an ashram with a focus on a spare, meditative existence devoid of dogma. The charisma of the founders and their teachings attracted a diverse international following that continues to this day. Early visitors to the ashram included the photographer Henri Cartier-Bresson, and architects Antonin Raymond and George Nakashima.

Raymond and Nakashima's narratives of their time in Pondicherry deal primarily with the peace and beauty they experienced in the idyllic ashram setting. It is clear from their accounts that in 1935, Antonin Raymond's architectural office in Tokyo received a commission for the design of a new residential dormitory for the ashram. Raymond had been recommended by Philippe B. St. Hilaire (Pavitra), a French engineer and ashram devotee, who had befriended Raymond in Japan. The French government had expressed concern at the growing influence of the Ashram and proposed that the ashramites refrain from any further purchases of property in the French section. A property adjacent to the local Tamil neighborhood was selected as the proposed site for the new building. Funds for construction were donated by Sir Akbar Hydari, Prime Minister of the prosperous state of Hyderabad, as a token of gratitude. His son, Ali Hydari, had sought and received solace in the ashram community. The renowned Golconda diamond mines, located in Hyderabad, were the source for the dormitory's eventual name, Golconde.

Antonin Raymond first arrived in Japan in 1919 to serve as project architect for Frank Lloyd Wright's Imperial Hotel in Tokyo. Raymond established his own architectural office in 1920 and was regarded as an innovative, modern architect, known for incorporating traditional Japanese aesthetics and methods of construction in his work. He also pioneered the use of reinforced concrete in Japan.

The task of making a preliminary site visit had been assigned to George Nakashima, who was then working as an architect at Raymond's office in Tokyo. Schematic design for the dormitory project was completed in early 1936. The construction supervision was entrusted to Nakashima and Francois Sammer—a Czech architect who had worked for Le Corbusier in Russia before joining Raymond's staff. The ingenuity of Raymond's design and the absence of skilled contractors in Pondicherry, posed a particular dilemma for the construction of the building.

> *In the architecture of today we endeavour to get back to the primary values so as to respond directly to the physical and spiritual needs of man without being subject to the prejudices that for the past centuries have restrained us and from which the style and forms of the buildings in Pondicherry have emerged. We are laying the foundation of a new kind of architecture found on the principles and not habits of the mind. Just as in your philosophy: aiming at the very outset for a mind that is free, a mind open and as much as possible disentangled from preconceived ideas."*[2]

Nakashima returned to Pondicherry in 1936, and spent the next two years as both an ashram devotee (he adopted the Indian name *Sunderananda — one who delights in beauty*), and a project architect. As project architect, Nakashima developed many of the building's careful construction methods and details on site. During his stay, he maintained a meticulous diary of the construction progress (a practice followed by several members of the ashram, as a way to regularly communicate with the Mother) and dutifully submitted it to the Mother for her commentary.

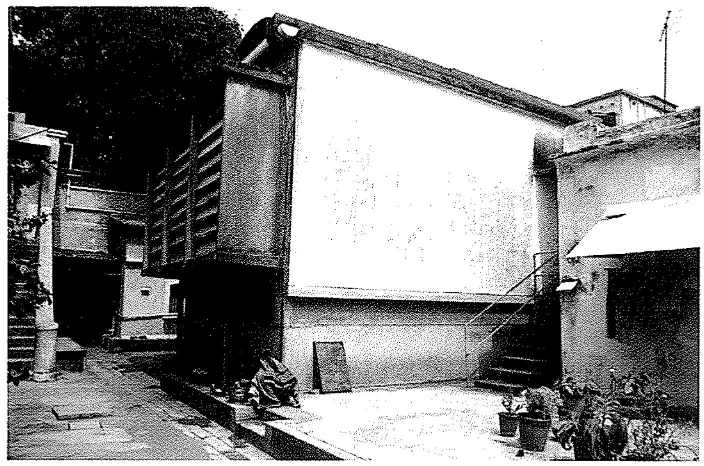


Figure 1 Picture of Model House / photograph by Ashok Dilwali

The architects constructed a full scale 'model house' in a temple compound adjacent to the site. This experimental building served as a laboratory for refining many of the construction materials and details.

Although Raymond originally envisioned a six-month time frame for construction, this schedule did not account for Sri Aurobindo's desire to protect the tranquil ashram environment from the din associated with a commercial construction company. Thus a workforce comprised solely of members of the ashram began construction. They were supervised by Nakashima, Sammer, and Chandulal (a devotee of Sri Aurobindo who had trained as an engineer). In order to test the feasibility of the design, the architects constructed a full-scale mock-up in a temple compound adjacent to the site (figure 1). This experimental "model house" served as the laboratory for refining many of the construction materials and details, and continues to serve as a primary residence for a member of the ashram today.

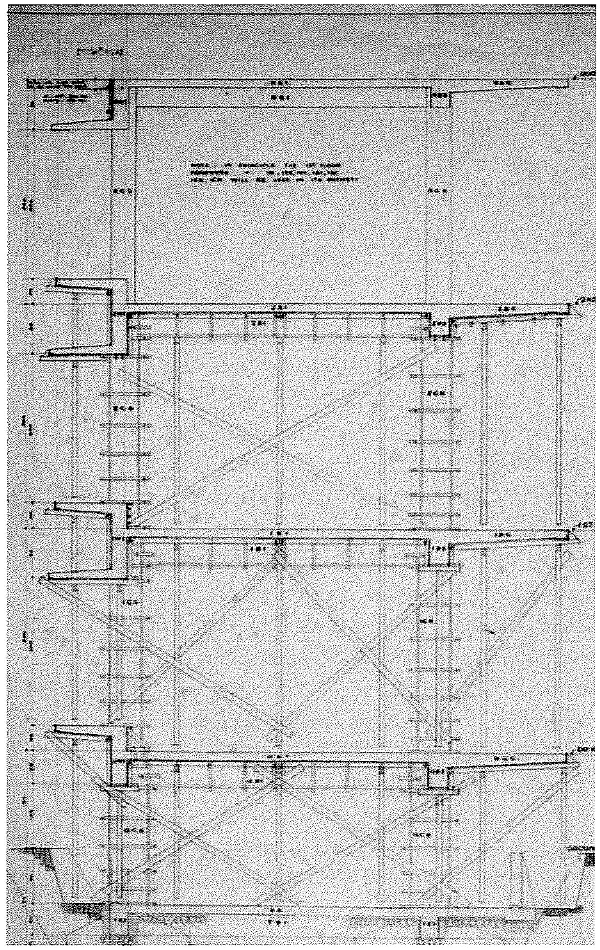


Figure 2 Formwork Section / archival drawing

Leading a team of untrained ashram devotees, George Nakashima carefully guided construction with many sheets of explicit construction drawings. This section showed the ashramites how to brace the formwork while the concrete cured.

By 1937, the imminent threat of war compelled Raymond to close his Tokyo office and leave Japan. Arriving with his family in Pondicherry, Raymond spent a few months at the ashram before returning to the United States. Nakashima and Sammer were entrusted with the completion of the project. Due to the absence of an experienced construction crew, Nakashima's duties included the preparation of detailed drawings for the construction of the concrete form work (figure 2). Chandulal supervised the on-site scheduling of materials and labor and Sammer took charge of completing the construction drawings. Due to the political unrest in Asia and Europe, many of the materials and hardware originally stipulated in the building specifications could no longer be imported. The development of alternative solutions on-site became necessary. In order to cast all metal hardware components stipulated in the design drawings, the architects constructed a foundry on the building site. The devotees of the Sri Aurobindo Ashram donated brass utensils, including cups, bowls, and plates. These were melted and recast as bolts, hinges, and door handles.

George Nakashima left India in October 1939, having completed most of the concrete work for the structure. After Nakashima's departure, Udar Pinto assumed the task of supervising the construction. Udar, an Indian aeronautical engineer, and his British wife Mona had joined the ashram in 1937. Sammer continued to work on completion of the drawings and the design of the furniture. Like Nakashima, Udar consulted with the Mother on all decisions pertaining to the design. Golconde was substantially completed in 1942 and continues to serve as a dormitory for devotees in Sri Aurobindo's Ashram.

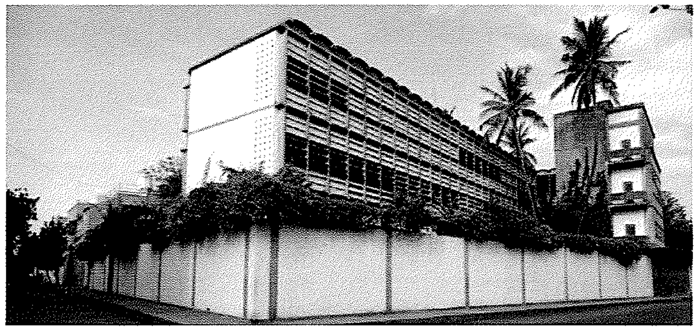


Figure 3. Exterior view from Southeast / photograph by Ashok Dilwali

This early morning south-eastern view, illustrates the boundary wall with its elevated garden, the stair tower, and the operable concrete louvers on the northern facade. The precast, thin-shelled concrete roof vaults create a buffer from the tropical solar exposure, and facilitate drainage during the intense monsoon rains.

BUILDING

> *Since Pondicherry didn't have a wharf, the steel was brought in from a freighter anchored in the Bay of Bengal on boats made of palm trunks lashed together. By the time they were unloaded on the beach, the steel rods had been bent so that they looked like a mass of spaghetti. From the shore they were dragged by bullock carts to the building site, where long lines of laborers hammered them straight.*[3]

Golconde remains a remarkable architectural edifice, seamlessly negotiating the tenets of early modernist architecture, while addressing the pragmatic impositions of a tropical context (figure 3). Presented with the condition of a hot and humid climate, Raymond sought a design solution that would mitigate the effects of the Pondicherry weather. The building is sited such that the major façades are oriented toward the north and south, availing of the breeze (figure 4). The landscape plan situates lines of water channels and reflecting pools along the northern and southern gardens; furthermore, the northern garden has a spare ground cover, whereas the southern shade garden has been densely planted with trees. The temperature differential between the northern and southern gardens facilitates natural convection currents through the building.

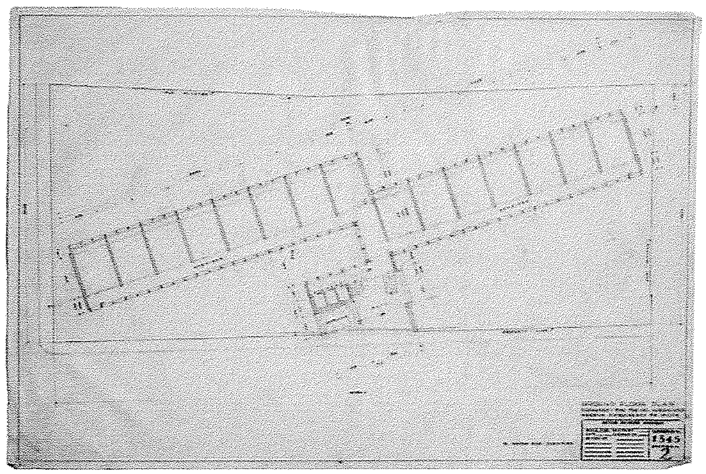


Figure 4 Ground Floor Plan / archival drawing

Taking advantage of a slender site, the plan layout offers maximum exposure on the northern and southern facades while absorbing a minimal heat gain on the slim eastern and western facades. Oriented towards a public street to the north, the stair tower and corridor serve as a buffer allowing each room a direct, more private relationship with the cooler southern garden.

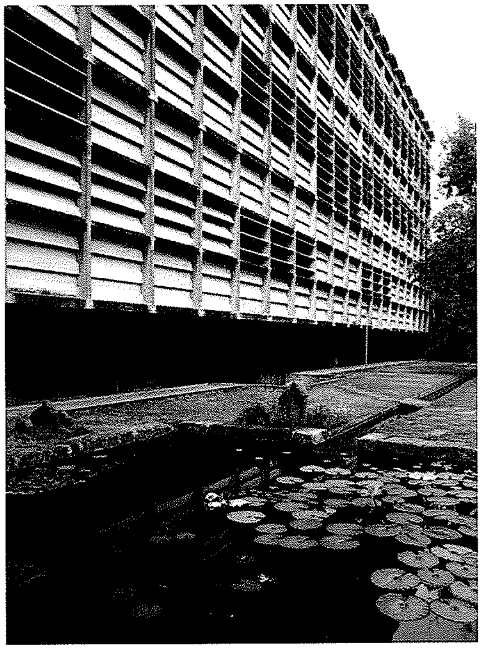


Figure 5 View of lotus pond and south façade / photograph by Ashok Dilwali

The most striking feature of Golconde is the skillful integration of the building with its landscape. The abstract permutations of the operable concrete skin are balanced with the serenity of the lotus pool and garden—a calm and meditative environment for devotees.

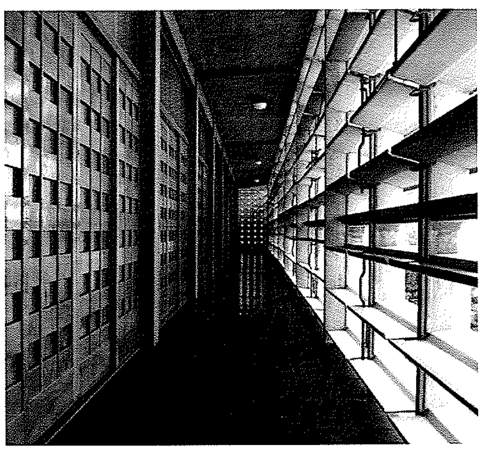


Figure 6. Interior Corridor / photograph by Ashok Dilwali

The north facing interior corridors facilitate a passive solar strategy for convection cooling. The sliding panels consist of staggered strips of teak wood, allowing for the passage of breeze, while maintaining visual privacy. Operable concrete louvers ensure constant air circulation between the north and south facades.

Figure 7 Central Stairwell / photograph by Ashok Dilwali

The seemingly utilitarian service core comprising of the main staircase and bathrooms achieves a simple grandeur by connecting earth and sky. Each handrail consists of a single board of oiled teak, anchored into the precast banisters with custom brass hardware.

The immaculately maintained building uses a spare material palette: reinforced concrete primary structure, bowed concrete shell roof, and polished Cuddapah (a local slate) floors. The building's presence on the street is anomalous; an exposed concrete wall with an oversize teak door, devoid of any ornamentation except for a small lotus—the Mother's chosen flower. The entry door leads into a garden where the first signs of activity in the self-contained community are perceptible. The partially excavated ground floor serves as the functional hub, containing dining and laundry facilities. This subtle siting gesture allows the residential upper floors to maintain a privacy; as the building is lifted above pools and gardens, it is undisturbed by the routine arrivals and departures of visitors and devotees. From the exterior, the building has a surreal, abstract quality (figure 5). The facades are modulated with operable asbestos cement louvers set in custom-made brass hardware. Sliding teak doors separate the interior rooms from a main, single-loaded corridor (figure 6). The crushed seashell plaster walls and black stone floors of each room provide a luminous canvas for the mélange of breeze and light entering through the louvers and sliders. The central core, containing the main stair as well as the bathroom units, services the building (figure 7).

The most striking feature of Golconde is the skillful integration of the building with the surrounding landscape. Shifts in scale from structure to detail, and transitions between exterior and interior, occur with grace and precision. Golconde remains architecturally vital, not solely for its technical finesse or extraordinary craft, but as a living testament to the original modernist credo—architecture as the manifest union of technology, aesthetics, and social reform. Within Pondicherry's unique cultural setting, Golconde offers an undiluted view of a wholly triumphant Modernism, where exemplary tectonics and exceptional construction are manna for a sophisticated and evolved community.

CONCLUSION

Given our current professional engagement with sustainability, it seems fitting to examine little-known historical precedents where the symbiosis between design, construction, and the environment remains exemplary. The conceptual force of Golconde's design solution remains radical even by the standards of today. In articulating an unambiguous stance toward minimal resource consumption, the building nonetheless champions a unique aesthetic. Eschewing the prevailing stylistic norms, Golconde proposes a visual identity that constantly affirms the primacy of its environmental agenda: a protective skin of manually operable louvers, a roof system where concrete roof tiles create an insulating zone above the concrete roof deck, woven teak-wood sliding doors that permit the passage of breeze without compromising visual privacy, and a system of pools and gardens that cool the ambient air.

The story of Golconde—in both design and construction—remains quintessentially international. Having outlived its designers, it celebrates their ideals of a progressive vernacular modernism, simultaneously resonant in the local and universal context.

RESEARCH METHODOLOGY

Our archival research on Golconde has focused on recording the correspondence between the Sri Aurobindo Ashram and the architects, reproducing existing architectural drawings, and cataloguing any previously unpublished documents relating to the building, including the notebooks of George Nakashima, Udar Pinto, and Chandulal. During our research visits to Pondicherry, we compiled a bibliography of published texts (books and journal articles) by Antonin Raymond, George Nakashima, Sri Aurobindo, and the Mother, pertaining to the design and construction of Golconde. Interviews with several members of the ashram have enabled us to sequence significant aspects of the evolution of Golconde: Raymond and Nakashima's time in India, Udar Pinto's contributions to the completion of the building, the notable involvement of several members of the ashram during the construction, and the role of the Mother as client—marshalling the talents and skills of disparate personalities to ensure a completed work of uncompromising quality.

A vital part of our work in Pondicherry involved preservation of original drawings: design drawings produced by Raymond's office, as well as on-site drawings by Nakashima and Sammer. Housed for over sixty years in Golconde and maintained by the Ashram Archives, they have deteriorated rapidly, a result of the acid in the paper and the humid climate. After sorting and cataloguing over two hundred original sheets, fifty sheets have been photographed (6cm x 7cm color transparencies) and reprinted to the original size. We scanned and printed archival photographs of Nakashima, Sammer, Udar Pinto, and any surviving images of the construction process. For our photo essay, we commissioned the services of Ashok Dilwali, one of India's foremost professional photographers.

NOTES

1. Antonin Raymond, *Antonin Raymond; An Autobiography* (Rutland, Vt.: C. E. Tuttle, 1973).
2. Antonin Raymond, letter to Philippe B. St. Hilaire, n.d.
3. George Nakashima, *The Soul Of A Tree: A Woodworker's Reflections* (New York, N.Y.: Kodansha Intl., 1981), 64.

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Produced by
The American Institute of Architects
1736 New York Avenue, N.W.
Washington, D.C. 2006

Barbara Sido, CAE
Team Vice President, Knowledge

In association with
School of Architecture
College of Architecture and the Arts
University of Illinois at Chicago
845 W. Harrison Street
Chicago, IL 60607

Daniel S. Friedman, Ph.D., FAIA, Director
Francine Hoerrmann, Associate Editor

Designed by
Jason Pickleman
The JNL Graphic Design
Chicago IL

Printed by
Original Smith Printing
Bloomington, IL

ISBN 0-9727266-4-0