INTRODUCTION
Architectural practitioners conduct research all the time to:

- Stay abreast of client trends
- Gather data on project programs and sites
- Survey the relevant work of colleagues
- Investigate the performance and availability of products and systems
- Evaluate options during construction
- Monitor building performance after its completion

Despite the prevalence of research in practice, however, relatively few architects have training in research methods or a full understanding of the range of architectural research being done. The goal of this chapter is to begin to fill that gap.

Architectural research has characteristics of both scientific or technical research, on one hand, and artistic or humanistic research, on the other. Christopher Frayling, rector of London's Royal College of Art, has argued that all research in architecture revolves around one of three prepositions.

- Research "for" design typically involves investigations of new technology, products, and materials.
- Research "into" design encompasses the social sciences and humanities, such as historical and environment behavior research.
- Research "through" design embraces creative production, with the design process itself as a form of discovering new knowledge.

Among these three types of architectural research exist different methods of investigation. Whereas scientific researchers ask testable questions, conduct replicable experiments, draw general conclusions, and communicate through peer-reviewed journals or databases, architectural practitioners engage primarily in a far more applied form of research. They ask questions particular to a project, gather information mostly from existing sources, make decisions based on these findings, and communicate them through such vehicles as memos, drawings, models, and contract documents.

If architects can be said to do "basic" research, it typically occurs through design. But unlike the basic research of science or social science, design discovers new knowledge in a less linear, more iterative way, based less on experiment than on experience, and conveyed less through written papers and more through competitions, exhibitions, magazines, and monographs.

Although research pervades architectural practice, it remains relatively invisible for a couple of reasons. The field does not have a long tradition of documenting and communicating the research that goes into the work of its practitioners, as opposed to publishing the results of investigations in the form of completed buildings. Most architectural publications, for example, give scant attention to the design process, the critical thinking, or the detailed discoveries that often occur in the act of designing and constructing buildings. And even if publications welcomed such material, many architects hesitate sharing it, given the strong sense in the field of the proprietary nature of the work. Perhaps because of the close working relationship architects have with the construction industry and product suppliers, they sometimes act like a trade, keeping secrets, rather than a profession, sharing knowledge.

That distinction has become particularly important now that designing and building have begun to merge in a variety of new delivery methods in response to changing market forces. As architects look for ways to distinguish themselves from their increasingly close contractor colleagues, research becomes a primary form of differentiation. By conducting and communicating research of all sorts, they increase their knowledge, raise their value, sharpen their identity, and improve the quality and performance of what they do.
THE NATURE OF RESEARCH

This section examines the nature of research in general and, specifically, the nature of architectural research.

WHAT IS RESEARCH?

Research "for" or "into" design almost always begins by doing research into the existing literature or knowledge of the subject. As Christopher Hart writes in Doing a Literature Review (Sage, 1999), such research often begins by asking the following questions:

- Who is the research for?
- What is the focus of the research?
- What questions am I trying to answer?
- How should I conduct the research?
- What key findings are already available?
- How and where have they been communicated?
- How do I find those add to my knowledge and to the knowledge of others?
- What are the next steps in the research?

Research "through" design in some ways inverts this process. As Jane Randell observed in her article "Architectural Research and Disciplinarity," in Architectural Research Quarterly (Cambridge, v3, n2, pp.141-147), "Practitioners will investigate ideas through the production of a work first and later consider for whom and how the knowledge generated is original." This recalls Donald Schön's idea of the "reflective practitioner," where, in his book by that same name (Basic, 1983), he suggests a different set of questions that researchers might ask "through" design:

- What is the specific problem that's being worked on?
- How can I describe it and demonstrate it in ways that a particular person or group will understand?
- How can I do it by building a relationship in which defensiveness is minimized?

Schön describes this as "reflection-in-action," in which practitioners learn by doing, coming together, with others who are trying to do the same thing.

- Create a virtual world (a drawing, a model) in which experiments can occur cheaply and without great danger.
- Learn how to use certain crucial media (computers, watercolors) to do the experiments in that virtual world.
- Interact with someone (colleagues, coworkers) in the role of coach, trying to help you do something, not only in words but also through performance.
- Engage in a dialogue of reciprocal reflection-action (in-house reviews, client meetings) where participants reflect on, and respond to, the message received from the other.

WHAT IS THE NATURE OF ARCHITECTURAL RESEARCH?

All good research, like all good design, has the following characteristics, according to Carole Grey and Julian Malins in Visualising Research (Ashgate, 2004):

- Breadth and depth
- Rigor and consistency
- Clarity and brevity
- Effective analysis and synthesis

And like design, research requires a high degree of creativity, arising from:

- Questioning: "Why's that ... ?"
- Imagining: "What if...? How about...?"
- Connecting: "Try linking this to that..."
- Interpreting: "Could this mean...?"
- Applying: "I'll try this out..."

Research, like design, also demands communicating with and convincing others through the following:

- Claim: An arguable statement
- Evidence: Data used to support the claim
- Warrant: An expectation that provides the link between the evidence and the warrant
- Backing: Context and assumptions used to support the validity of the warrant and evidence

When we make a claim, we need to ensure the following;

- Clarity: Is a statement expressed in the best way? How else could it be expressed? Is it sufficiently elaborated? Is there too much jargon/over-specialized language? Are there relevant examples or illustrations?
- Accuracy: Is this true? Can its accuracy be checked? Is it appropriately attributed?
- Precision: Is there enough detail to explain the meaning? Could it be more specific or more clearly defined?
- Relevance: How is this related to the topic? Is it truly relevant? Is it out of context?
- Depth: Are the complexities of the question addressed? Is the statement qualified by reason and evidence? Is it a superficial treatment?
- Rejection: Are there issues that have been omitted? Is there another way to look at this? Are there other acknowledged perspectives on this? Is there evidence provided?
- Logic/reason: Does this really make sense? How does this follow from what was said before? Is it consistent? Does this contradict the previous statement?

GOOD AND BAD ARCHITECTURAL RESEARCH

How do we recognize good—and bad—research when we see it? Like the best design, good research, says Leonard Bachman, in materials from his University of Houston course "Architectural Inquiry," has the following characteristics:

- Incorporates wisdom that has been previously learned about architecture and is in agreement with currently known facts.
- Summarizes and evaluates the research results and supports its findings with appropriate graphics and tables.
- Discusses similarities and differences between its results and previous work by others in the same topic field(s).
- Identifies the tactics, strategies, methods, processes, and conduct of the actual research activities undertaken.
- Is comprehensive and helps to explain a wide range of architectural problems rather than one specific case.
- Is parsimonious; that is, is as simple as possible in its explanation; is elegant and thorough with its language; and uses no more concepts, facts, or theories than are absolutely needed to explain the topic. According to Occam’s razor, “One should not increase, beyond what is necessary, the number of entities required to explain anything.” Keep it narrow.
- Is not cluttered by repetition or reformulated statements.
- Is written for an audience with a high threshold of common knowledge and focuses on the research topic without overly explaining its background or restating existing knowledge.
- Is verifiable by exact replication of the research methods, with minimal possibility of alternate interpretations.
- Is provocative of further thought, theorizing, and research.
- Is useful for predicting, understanding, changing, and controlling architectural challenges in practice.
- Is unbiased and objective so that, within the assumptions and limitations stated, its results are generally shared by experts.
- Is consistent and clear in its use of terms, definitions, and philosophical positions.
- Is scaled to defined conditions within which the results are relevant and outside of which the results are less useful.
- Is independently self-supported and self-explanatory to a knowledgeable audience and does not require clarification by the researcher to convey or “prop up” its meanings.
- Is transformational in its conception, design, execution, and results to the extent of changing how we think about the topic in at least some small way.

But architectural research, like architectural design, is also often misunderstood, often by too superficial a view of what it entails. It is not merely a matter of much they get reprocessed or redesigned.
- A report
- Work performed for growth of personal knowledge about existing information
- Aimsless speculation about the way things should be
- Confirmation of a subjective idea, belief, or opinion you already have without critically questioning it or without establishing that it might be flawed—research is not the pursuit of self-serving logic
- Vague references to a narrow scope of ideas within a vast topic
- News about recent developments
- A lot of data and answers without an essential question
- Concern with broad topic areas that cannot be exhausted by one finite research project
- Overly subjective, abstract, or aposphenoid discussions that can neither be proven nor disproved
- A fishing expedition with prospects founded solely on general interest, luck, stubbornness, and serendipity
- Something that can be completed on the Internet
- The path of least resistance
- Earthshattering, any more than any single good work of architecture has established a whole new paradigm

THE PROCESS OF ARCHITECTURAL RESEARCH

Research "for" or "into" and "through" design moves through certain predictable steps, like the phases of design. According to James Snyder in the book Architectural Research (Van Nostrand Reinhold, 1995), these steps involve:

- Hypothesis formation or problem formulation: What are we looking for? What do we think we'll find?
- Deduction: What do we want to look for? What do we want to find?

RESEARCH APPROACHES

15.1

<table>
<thead>
<tr>
<th>APPROACH</th>
<th>DESCRIPTION</th>
<th>DETAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deduction</td>
<td>Specific belief based on a general situation</td>
<td>Starts with generalization and moves toward observations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Works from an image backward to the means to achieve.</td>
</tr>
<tr>
<td>Induction</td>
<td>General beliefs from many similar cases</td>
<td>Starts with observations and moves toward generalization.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Works from a set of principles toward ways of achieving it.</td>
</tr>
<tr>
<td>Hypothetically deductive</td>
<td>Back and forth from general to specific</td>
<td>Starts with either a general situation or a particular case.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Works from either theory or evidence toward the other.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Works back and forth in an iterative process.</td>
</tr>
</tbody>
</table>
The way we approach research, like the way we approach design, also depends on our decision-making styles. Research has shown that people have different ways of making decisions, having to do with both control and how strong a goal they have. According to John Wade in Architecture, Problems, and Purposes (Wiley, 1977), these decision styles are as indicated in Table 15.3.

### Decision Styles

<table>
<thead>
<tr>
<th>Decision Styles</th>
<th>Strong Control</th>
<th>Weak Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong goal</td>
<td>Determine</td>
<td>Impose</td>
</tr>
<tr>
<td></td>
<td></td>
<td>an overall</td>
</tr>
<tr>
<td></td>
<td></td>
<td>order</td>
</tr>
<tr>
<td>Work goal</td>
<td>Open-ended</td>
<td>Situational</td>
</tr>
<tr>
<td></td>
<td>Responsive</td>
<td>Responsive</td>
</tr>
<tr>
<td></td>
<td>to client's</td>
<td>to context's</td>
</tr>
<tr>
<td></td>
<td>order</td>
<td>order</td>
</tr>
</tbody>
</table>

At the same time, researchers, like designers, have different responses to change, depending on whether we see change as good or bad, as something to embrace or not; this is indicated in Table 15.4.

### Responses to Change in Research

<table>
<thead>
<tr>
<th>Response to Change</th>
<th>Change Bad</th>
<th>Change Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive to change</td>
<td>Hesitant</td>
<td>Optimistic</td>
</tr>
<tr>
<td>Resistant to all</td>
<td>Conservative</td>
<td>Responsive to any change</td>
</tr>
<tr>
<td>Active to change</td>
<td>Revolutionary</td>
<td>Quick to change, given new facts</td>
</tr>
</tbody>
</table>

### Types of Architectural Research

The range of architectural research remains quite broad, according to Linda Grant and David Wong in Architectural Research Methods (Wiley, 2002). We can categorize research according to its content or to the method used to conduct it.

### Types of Architectural Research

<table>
<thead>
<tr>
<th>Divided by Method</th>
<th>Divided by Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretive/historical research</td>
<td>Process of design and construction</td>
</tr>
<tr>
<td>Qualitative research</td>
<td>Building habitability</td>
</tr>
<tr>
<td>Correlational research</td>
<td>Human security and safety</td>
</tr>
<tr>
<td>Experimental research</td>
<td>Conservation of resources</td>
</tr>
<tr>
<td>Simulation research</td>
<td>Structural, material, equipment systems</td>
</tr>
<tr>
<td>Case study/mixed methods</td>
<td></td>
</tr>
</tbody>
</table>

---

Note: The diagram and text are connected to the content of the text, providing a visual representation of the research process and decision-making styles in architectural research.
ARCHITECTURAL RESEARCH

The Nature of Research

Architectural research also has a number of different outcomes, according to Richard T. Hayes, PhD, AIA, and David Wang in John McRae's AIA report, "Research: Challenges, Directions and Opportunities" (AIA, 2004), as shown in Table 15.6.

Most architectural research, however, exists somewhere between these quantitative and qualitative limits:

**Quantitative and Qualitative Research**

<table>
<thead>
<tr>
<th>Quantitative Research</th>
<th>Qualitative Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective and singular in focus</td>
<td>Subjective, with multiple foci</td>
</tr>
<tr>
<td>Researchers independent from research subject</td>
<td>Researcher interacts with research subject</td>
</tr>
<tr>
<td>Deductive process, with search for cause and effect</td>
<td>Inductive process, with mutual simultaneous factors</td>
</tr>
</tbody>
</table>

- Most design research involves both quantitative and qualitative evidence.
- Deduction and induction can relate to both quantitative and qualitative work.

Architectural research, while it is almost always directed to very practical applications, also ranges from basic to applied research as indicated in Figure 15.8, according the James Snyder in Architectural Research (Van Nostrand Reinhold, 1984).

**Basic and Applied Research**

<table>
<thead>
<tr>
<th>Basic Research</th>
<th>Applied Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge used to understand reality</td>
<td>Knowledge used to solve problems</td>
</tr>
<tr>
<td>Useful in the development of theory or hypotheses</td>
<td>Useful in addressing needs of a particular situation</td>
</tr>
<tr>
<td>Asking what something means or why it exists</td>
<td>Asking what something is or how it is improved</td>
</tr>
</tbody>
</table>

Scholarship and Research

In academic circles, research often refers to investigative work that has outside funding, with a sponsor, while scholarship refers to work that has little or no outside funding, done out of a desire to know. Both occur in architectural research, in part because of the multidisciplinary nature of the field, which embraces everyone from engineers and scientists to historians and theorists to artists and designers. Ann Forsyth and Katherine Crewe have laid out the difference between research and scholarship in their article, "Research in Environmental Design: Definitions and Limits," in the Journal of Architectural and Planning Research (summer 2006, pp. 160-175).

**Scholarship and Scholarship**

<table>
<thead>
<tr>
<th>Scholarship of Discovery</th>
<th>Scholarship of Integration</th>
<th>Scholarship of Application</th>
<th>Scholarship of Teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connection of research and design via discovery</td>
<td>Research and design inherently interdisciplinary</td>
<td>Apply knowledge to problem of the community and society</td>
<td>Research an extension of teaching, and vice versa</td>
</tr>
<tr>
<td>Research and design complement each other</td>
<td>Incorporate and connect to knowledge from other disciplines</td>
<td>Research and design as means, not ends in themselves</td>
<td>Research integrated with design education</td>
</tr>
</tbody>
</table>

Types of Scholarship

<table>
<thead>
<tr>
<th>Theory</th>
<th>Tools</th>
<th>Standards</th>
<th>Narrative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptive theory, describing an outcome, objective, or end result</td>
<td>Computer software, developed to facilitate rudimentary tasks</td>
<td>Design guidelines, a statement/policy regarding material and methods relationships</td>
<td>Historical account, background information stating the context of an event</td>
</tr>
<tr>
<td>Explanatory theory, explaining cause, effect, and outcome</td>
<td>Computer model, developed to evaluate a solution prior to acceptance</td>
<td>A program, a statement/policy regarding spatial relationships</td>
<td>Thick description, explaining a contemporary social-cultural phenomenon</td>
</tr>
<tr>
<td>Predictive theory, predicting outcome given cause and effect</td>
<td>Assessment matrix, developed to rank and order items, tasks, and outcomes</td>
<td>Policy or policy recommendations, a course of action or guiding principle</td>
<td>Statistical listing, story or account of commentary or existing mathematics</td>
</tr>
<tr>
<td>Theory of persuasion, determining the outcome and the required cause and effect</td>
<td>A recipe or general procedure, developed to achieve homogeneous results</td>
<td>A checklist, a list to compare, schedules, verify, or identify items or topics of discussion</td>
<td>A code, a comprehensive and systematically arranged collection of regulations/rules</td>
</tr>
<tr>
<td></td>
<td>A product, developed either as a direct result or to achieve a desired result</td>
<td>Instructions, an authoritative direction and sequence</td>
<td>Forms, a document with blanks for the insertion of details or information</td>
</tr>
</tbody>
</table>

Parallel to this, Ernest Boyer and Lee Milgang, in their book Building Community: A New Future for Architecture Education and Practice (Cambridge, 1990), have identified different types of scholarship, ranging from the traditional "scholarship of discovery" to a range of less common notions of scholarship "through" learning, practice, and teaching, all of them relevant to the varied ways in which architects work. These are itemized in Table 15.10.
TECHNICAL RESEARCH

RESEARCH "FOR" DESIGN

The research "for" design that occurs in architecture studies investigations of the technologies, tools, methods, and materials used in designing and constructing the built environment. Some of the basic research in this area gets done in university or architects' research labs, while most of it gets applied in architectural offices or at construction sites.

The 1997 Architectural Research Centers Consortium conference, Ronald Watson and Walter Grondzik conducted an informal survey of architectural researchers (ARCC), educators (IUS), and practitioners (AIA, PIA) to explore the idea of a strategic research agenda. The results show priorities of research interest.

A database summarizing and categorizing the architectural and design-related research in print (www.informedesign.umn.edu) provides one way of strengthening this knowledge loop, enabling researchers to gain access to research information and practitioners to get their results into the hands of practitioners. The following categories in Informedesign, developed by Denise Guerin and Craig Martin at the University of Minnesota, with support from AIA, shows one way of categorizing the results of architectural research.

<table>
<thead>
<tr>
<th>SPACE</th>
<th>ISSUES</th>
<th>OCCUPANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate</td>
<td>Building materials, finishes, and systems</td>
<td>Ability/disability</td>
</tr>
<tr>
<td>Entertainment</td>
<td>Codes and safety</td>
<td>Age</td>
</tr>
<tr>
<td>Facility management, planning, and design</td>
<td>Design and aesthetics</td>
<td>Education</td>
</tr>
<tr>
<td>Environment/ situational</td>
<td>Design business and process</td>
<td>Gender</td>
</tr>
<tr>
<td>Health care</td>
<td>Furnishings, fixtures, and equipment (FF&amp;E)</td>
<td>Race/ethnicity</td>
</tr>
<tr>
<td>Hospitality/restaurant</td>
<td>Personal/individual needs and factors</td>
<td>Socioeconomic standing</td>
</tr>
<tr>
<td>Outdoor space</td>
<td>Social needs and factors</td>
<td>Type</td>
</tr>
<tr>
<td>Residential</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retail/store planning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sports and fitness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainable design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universal design</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SUMMARY OF THE NOMINATED STRATEGIC AGENDA TOPICS

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>AIA (%)</th>
<th>ARCC (%)</th>
<th>COMBINED (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustics</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Aging society issues</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Building codes/practices—international</td>
<td>7</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Building materials</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Civic architecture and design</td>
<td>20</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Diverse, cultural, minorities</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Earthquake mitigation</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Education of architects</td>
<td>2</td>
<td>19</td>
<td>2</td>
</tr>
<tr>
<td>Energy and environmental sustainability</td>
<td>22</td>
<td>1</td>
<td>29</td>
</tr>
<tr>
<td>Health facilities</td>
<td>2</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Indoor air quality</td>
<td>9</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Information management/automation</td>
<td>7%</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Justice facilities</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-cost housing</td>
<td>12</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Productivity</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Religious art and architecture</td>
<td>2</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Technology and the building environment</td>
<td>7</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Testing and evaluation</td>
<td>2</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Transportation</td>
<td>2</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
ARCHITECTURAL RESEARCH

BUILDING SYSTEMS RESEARCH

Research into materials, systems, and assemblies in buildings comprises a large area of investigative work, "for" design. An example of this work is research into the performance of foundation envelopes and interior systems. Research in the past decades has focused on the energy and moisture transport characteristics of the foundation envelopes, with a view to providing economically optimized thermal performance without sacrificing durability and, in particular, avoiding failures commonly caused by fungal biotic activity. In the future, research will focus more on integrating the foundation into the self-sustaining energy infrastructure of the entire building by housing solar, wind, and bioclimatic renewable energy systems, coupled with hydrogen storage and thermal/electrical energy conversion systems. Additional areas of research include parenthesis of structural systems, isolation of the foundation from soil and ambient liquid and gaseous pollutants, and the development of sustainable insulation systems to replace their fossil fuel-derived counterparts, which are increasingly becoming more expensive and environmentally unacceptable.

The principal research approach used for translating physical concepts into practical designs is to create mathematical models of the foundation systems and to use these models to evaluate and refine the designs via computer simulation. Typically, these models include full three-dimensional multiphysics phenomena and are solved with finite element or computational fluid dynamics numerical computation techniques. The optimized designs are then experimentally validated in full-scale, field-laboratory research facilities over at least a full calendar-year period. The transient experimental data thus gathered are used to validate the mathematical models that, in turn, can be used for further design refinement and evaluation of the design under different climatic and interior boundary conditions.

Such building foundation research is funded primarily by the private sector in the course of developing and funding new building products. Public funding (principally from state and federal grants) forms an ever-decreasing component of the available resources.

The case study described here is an example of this research methodology and environment. The research is of fundamental relevance to the construction of all buildings not only in terms of design practice but also in terms of the development of adequate building codes.

More than 20 years of research on the hydrothermal performance of building foundations at the University of Minnesota has resulted in the development of a performance standard for designing building foundation insulation systems. This performance standard is expressed as the following definitions, performance requirements, and criteria:

DEFINITIONS

- **Foundation:** Comprises a floor system and exterior perimeter wall system in contact with the earth.
- **Foundation wall system:** A continuous and homogeneous vertical structural system, a portion of which must be in contact with the earth.
- **Foundation floor system:** A continuous and homogeneous horizontal structural or nonstructural system in contact with the earth.
- **Water separation plane:** A single component or a system of components creating a plane that prevents liquid water capillary and hydrostatic pressure driven flows and provides a water vapor permeance of 0.1 perms or less to retard water vapor flow by diffusion.
- **Foundation air barrier system:** A material or combination of materials that the following characteristics:
  - Is continuous, with all joints sealed.
  - Is durable.
  - Resists the transport of an air/water vapor mixture as a result of an exterior/interior pressure difference to the minimum extent necessary to achieve moisture durability and a given level of energy efficiency.
- **Stable annual wetting/drying cycle:** A water (solid, liquid, and vapor) transport process operating on a foundation that produces no net accumulation of ice or water over a full calendar year and is free of adsorbed water for at least four months over a full calendar year.
- **Foundation insulation layer:** A system of building materials connected in series and/or in parallel, excluding surface heat transfer film coefficients, that serves as thermal insulation in foundation wall and floor systems.
- **Foundation wall system energy trade-off zone:** The portion of the wall from the base of the footing to a maximum above-grade extension of 12 in.

CONCRETE MASONRY INTERIOR THERMAL INSULATION WALL ASSEMBLY

15.13

- **UV/WEATHERING PROTECTION IF REQUIRED BY WATERPROOFING MANUFACTURER**
- **REINFORCING STEEL PER R404.1.1**
- **WATER SEPARATION PLANE EXTENDING FROM WALL TOP TO OUTER TOP EDGE OF FOOTING WITH**
  - (A) PERMEANCE: 0.1 PERM MAX (ASTM E 969)
  - (B) VAPOR RETARDER EXTENDING TO INTERSECT WATERPROOFING PERMEANCE: 0.2 PERM MAX (ASTM E 969)
  - (C) FOUNDATION DRAINAGE TO ROOF (WITH FILTER FABRIC)

- **FRAME: Fungal resistance ASTM G 21 or equivalent**
- **CAP BLOCK OR EQUIVALENT**
- **CONCRETE MASONRY BLOCK PER ASTM C 90**
- **THERMAL INSULATION (SUCH AS FIBERGLASS BOARD) WITH REQUIREMENTS:**
  - (A) DENSITY: 29 PCF MIN
  - (B) R-VALUE: R-10 MIN
  - (C) Fungal resistance: ASTM C 1388
- **INTERIOR FINISH AS REQUIRED FOR FIRE AND THERMAL PROTECTION PER R304.1.2 WITH ADDITIONAL REQUIREMENTS:**
  - (A) NET PERMEANCE: > 50 PERM
  - (B) Fungal Resistance: ASTM G 21 or equivalent

- **STRUCTURAL COUPLING AS REQUIRED BY R403.1 OR AS NECESSARY TO ANCHOR BOTTOM COURSE TO FOOTING**
- **6-MIL POLYETHYLENE UPPER RETARDER OR EQUIVALENT SEAL TO WALL SURFACE**
- **BOARD INSULATION (ASTM C 570) TYPES X, IV, V, VI OR VI**
- **4" THICK MIN, 3/8" MIN. COMPACTED STONE LINKED TO FOUNDATION DRAINAGE**

TECHNICAL RESEARCH

REQUIREMENTS

A building foundation must be designed to meet the following requirements:

- Have a continuous water separation plane between the exterior and interior.
- Prevent external liquid water intrusion (including capillary flow) across the water separation plane after the foundation is backfilled.
- Have a foundation air barrier system between the interior and exterior.
- Have a foundation wall system insulating layer with a minimum equivalent continuous uniform thermal resistance within the foundation wall system energy trade-off zone without any thermal breaks optimized for local climatic conditions using measured and/or simulated three-dimensional energy flux data.
- Prevent structural failure by means of frost heave or soil structure defreezing.

CRITERIA

On the interior side of the water separation plane, a building foundation system must be designed to have:

- A stable annual wetting/drying cycle
- No visible or olfactory fungal or other biotic activity
- No bulk water movement
• There are components of the foundation wall system inside the water separation plane designed specifically to absorb and store moisture so that there is no accumulation of free water on the interior side of the water separation plane when at least 63 percent of the foundation wall system height is above grade.

This performance standard has been applied to the design of three innovative, full-basement interior foundation insulation systems (shown in the accompanying figures), and full-scale, long-term quantitative experiments have been conducted to verify the compliance of these systems with the previously mentioned performance standard. Each of these assemblies represents a different approach to compliance with the performance criteria in a cold Minnesota climate. The notations in the schematics refer to requirements in the 2003 International Residential Code.
OPEN-CELL SPRAY FOAMED-IN PLACE INSULATION WALL ASSEMBLY

15.15

UV/WEATHERING PROTECTION IF REQUIRED BY WATERPROOFING MANUFACTURER

WATER SEPARATION PLANE EXTENDING FROM WALL TOP TO OUTER TOP EDGE OF FOOTING WITH PERMEANCE TOGETHER WITH CONCRETE WALL, 0.1 PERM MAX. (ASTM E 968)

CAPILLARY BREAK MATERIAL EXTENDING TO OUTER EDGE OF WALL (ASTM D 41, D 1187, D 1227, D 4479, D 4566 OR EQUIVALENT)

DRAINAGE SYSTEM TO R403.1 (WITH FILTER FABRIC)

FIRE STOP FRAME TOP PLATE (SHOWN) OR EQUIVALENT

0.5 LB DENSITY FREE RISE, OPEN CELL SPRAY INSULATION CONTINUOUSLY ADHERED TO WALL SURFACE WITH:
(A) R-VALUE: R-10 MIN.

INTERIOR FINISH AS REQUIRED FOR FIRE AND THERMAL PROTECTION PER R314.1.2 WITH ADDITIONAL REQUIREMENTS:
(A) NO ADDITIONAL INSULATION
(B) MIN. NET PERMEANCE: 10 PERM (ASTM E 968)

STRUCTURAL COUPLING AS REQUIRED BY R403.1 OR AS NECESSARY TO ANCHOR WALL TO FOOTING

6-MIL. POLYETHYLENE MEMBRANE OR EQUIVALENT SEALED TO WALL SURFACE

RIGID INSULATION (ASTM C 578) TYPES X, IV, VI OR VII WITH R-VALUE: R-5 MIN. PER INCH

4" THICK MIN., 3/8" MIN. COMPACTED STONE LINKED TO PERIMETER DRAINAGE

Contributor:
Louise Goldberg, College of Design, University of Minnesota, Minneapolis, Minnesota.
SOCIAL SCIENCE RESEARCH

RESEARCH "INTO" DESIGN

Research "into" design typically involves the two social sciences closely linked to architecture: environmental psychology, which relates to activities such as the programming or postoccupancy evaluation of buildings, and history/theory, which allows one to draw conclusions about or develop general ideas for a project.

PROGRAMMING

Buildings begin with a statement of need and the development of a program, often in a pre-design stage of a project. One way to look at it is as the first of a three-part process in the creation of a building, as shown in Figure 15.16.

The three-part process also entails a constant checking back with a program to ensure that the identified needs are being met.

The "tests" of the design against the program can occur in at least four points, as shown in Figure 15.17:

1. In some countries and among some clients, the programming stage has been defined more specifically. For example, in The Netherlands, according to Theo van der Voordt and Herman van Wegen, in Ways to Study and Research Urban, Architectural, and Technical Design, building programming includes five areas:
   - Usage requirements: This should include the nature, size, organizational structure, and patterns of activities, now and in the future.

REF DEVELOPED FROM GLOBAL TO DETAILED


PLACE OF PROGRAMMING IN A TRADITIONAL BUILDING PROCESS

15.16


- Functions and performances: Relevant items, among others, are the spatial need for the building as a whole and per room, physical building conditions envisaged (temperature, light, humidity, sound, view), safety, and flexibility.
- Image expectations: What are the client's expectations in terms of the appearance of a project? What design guidelines or design review process might exist?
- Internal conditions: Conditions related to financial-economic conditions (e.g., cost-benefit analysis) and conditions related to time (e.g., date of completion) are among the issues to be addressed here.
- External requirements and conditions: This includes planning and zoning requirements, building codes, site requirements, security standards, and environmental policies, among others.

The methods for programming include:

- Documentation: This includes the use of interviews, questionnaires, analysis of documents, behavior mapping, workshops with users, and scenario building.
- Translation: Here, the organizational characteristics and functional requirements get converted into performance criteria, based on clients' experiences and the programmer's professional expertise.
- Site visits: Visits to the project site and to similar projects that might serve as a reference or a precedent often need to occur.
- Analysis: Programming also includes the review of postoccupancy evaluations of similar projects to see what has or has not worked well.
- Literature review: Searches for data, experiences with particular design solutions, stands, and guidelines are among the steps here.

During the referring of a design against the stated needs and goals in the program, designers must do what Edward Hulsbergen and Pity van der Schaat, in Ways to Study and Research Urban, Architectural, and Technical Design (DUP Science, 2002) call "ex ante" research, research about the consequences of a design before its realization. Often this involves seeing for unintended consequences or hidden effects, which often get revealed over time, as shown in Figure 15.18.
RELATIONSHIP BETWEEN TIME AND EFFECT

Ex ante research can take two forms:

- Comparing the design to the original brief: How does the design meet the program? Where has it veered? Does that reveal a problem with the design or with the brief itself?
- Testing the design against issues not stated in the brief: What are the unexpected or unanticipated consequences of a design? Are those consequences desired or not?

The judgment of design and its consequences also differs between practice and education, as shown in Figure 15.19.

FRAMEWORK TO MAP CONSEQUENCES

<table>
<thead>
<tr>
<th>EXPECTED</th>
<th>UNEXPECTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

THREE DESCRIPTIONS OF THE PLANNING CYCLE

POST-OCCUPANCY EVALUATIONS

The postoccupancy evaluation (POE) of buildings constitute one of the most important ways architects can learn from their mistakes and improve the performance of architecture. Key questions to POE, according to Theo van der Voordt and Herman van Wegen, include:

- Is a building used in accordance with the intentions of all involved parties?
- Are daily users satisfied with their accommodation?
- To what extent does the actual energy consumption fit the expected energy consumption?
- To what extent do laypeople and experts agree on its architectural quality?
- Is the building designed and constructed according to the standards of the building code?
- How did the planning process come about?
- On which considerations were the design decisions based?
- What kind of expertise was used in the programming phase, the development of the architectural concept, and other stages of the process?
- Was it characterized by an interaction of design and research and an effective participation by clients and users?
- To what extent did legislative prescriptions and economic constraints act on the design?

Another form of assessing buildings after completion is the building performance evaluation (BPE), which falls into four categories, listed in Table 15.21.

Although the focus of each evaluation depends on the goals or concerns of a building owner or user, the list of characteristics of a building that often get evaluated include those shown in Table 15.21.

<table>
<thead>
<tr>
<th>FUNCTIONAL ASPECTS</th>
<th>AESTHETIC ASPECTS</th>
<th>TECHNICAL ASPECTS</th>
<th>ECONOMICAL AND JUDICIAL ASPECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td>Quality of image</td>
<td>Fire security</td>
<td>Budget</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Beauty</td>
<td>Constructive safety</td>
<td>Costs of investment</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>Originality</td>
<td>Material/physical quality</td>
<td>Operation costs</td>
</tr>
<tr>
<td>Ergonomic safety</td>
<td>Order and complexity</td>
<td>Environment safety</td>
<td>Time investments and time planning</td>
</tr>
<tr>
<td>Social safety</td>
<td>Representation</td>
<td>Sustainability</td>
<td>Laws and legislation</td>
</tr>
<tr>
<td>Spatial orientation</td>
<td>Cultural/historical value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Territoriality, privacy, and social contact</td>
<td>Meaning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical well-being (light, sound, temperature, draft, humidity)</td>
<td>Potential for change, flexibility, and adaptability</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
HETEROGENEOUS GROUPS
15.24

Each group is composed of people with different experiences and at least some different interests and values. Discussions tend to be constrained, people with power tend to dominate. When differences become explicit, this can lead to conflict, position taking, or both. Opportunity for negotiation, increased understanding, compromise, agreement, and changes in attitude. Process requires advanced facilitation skills.

- Local characteristics
- Characteristics of the building
- Characteristics of the different spaces

EVALUATION PROCESS
15.25

The evaluation process itself involves a generic set of steps, regardless of the situation or when in the life of a building it takes place, as shown in Figure 15.25.

- Preparing
- Evaluating
  - Introductory meeting
  - Touring interview
  - Review meeting
- Sorting data
- Responding

- Inception
- Selection or production period (months to years)
- Move-in
- Occupancy period (years to decades)
- Disposal

The assessment of a building also depends on who participates in the process: provider (owner, manager) or users, who may raise different issues because of different roles and power relations, as Kernohan and his coauthors have observed in User Participation in Building Design and Management, and as shown in parts 15.23 and 15.24.
In terms of a building itself, the analysis of it takes two forms:

- Morphological analysis: This involves looking at the specific characteristics (what and how) of the work in order to compare it to others and to put it in a broader perspective (why). This can include the formal, functional, and structural aspects of the work, or its stylistic or conceptual aspects.
- Technical analysis: This can include looking at the site or material of a building or the construction methods used in it.

Evaluating the physical fabric of a historic building, says Barry Richardson in Defects and Deterioration in Buildings (Spon, 2001), involves its own particular investigative process that involves the following tools:

- Moisture meter to assess moisture content of wood and other materials and assemblies
- Borescope and a small mirror to look into inaccessible or hard-to-see places
- Utility knife, claw hammer, crowbar, chisel, screwdrivers, saw, and electric drill
- Camera, plastic sealable bags or sealable envelopes for samples
- Sectional ladder, flashlight, notebook, waterproof pens or pencils

Research into the history and conditions of existing structures constitutes one of the largest areas of architectural research because of the widespread reuse of buildings. The following case study, by Harry Hunderman and Richard Weber of Wisz, Janney, Elstner Associates, offers some insight into how this is done.

CASE STUDY: BUILDING DIAGNOSTICS

The development of appropriate repair methods arises from a thorough understanding of the condition and behavior of structures and construction materials. For each project, this understanding is gained through the use of selected diagnostic techniques. A wide variety of tests exist to help in the evaluation of existing conditions, diagnosis of problems, and development of appropriate methods of repair. The case study described here illustrates the diagnostic process.

BACKGROUND

An investigation was performed to determine the causes of masonry distress and water leakage observed on a mid-rise building constructed in the 1950s in the northern United States. The exterior walls consisted principally of cavity wall construction with brick masonry cladding backed up by cold-formed metal framing. The steel studs were covered with exterior gypsum sheathing with a building paper weather barrier. A drainage cavity existed between the brick veneer and the building paper, with the weight of the brick supported by the foundation and by sheaf angles at floor slabs. Precast concrete lintels and sills occurred at all windows. In this system, water that penetrated the brick veneer was intended to flow down within the drainage cavity behind the masonry to flashings installed at the sheaf angles and lintels, and drain to the exterior through weep installed in the flexible flashing.

The windows consisted of a thermally improved, aluminum-framed system, with fixed insulating glass (IG) units. The window assembly typically had two IG units with an intermediate vertical mullion and a thermally improved aluminum sub sill, with end caps extending beneath the full length of the window. Aluminum and glass curtain walls extending several stories in height also interrupted the brick masonry cladding at several areas.
INVESTIGATION
Problems observed in the exterior cladding included outward displacement (bulging) and cracking of the masonry and water leakage into the interior at various locations. The purpose of the investigation was to determine the causes of distress and leakage, evaluate the extent of the problems, and provide direction for repairs.

REVIEW OF DOCUMENTS
Prior to the field investigation, original architectural and structural documents were reviewed, as well as shop drawings and submittals from original construction. In addition, the review of maintenance records helped to understand the nature of existing construction and past problems and repairs.

VISUAL SURVEY
Following review of available documents, a visual survey of the building exterior walls was performed from grade, using binoculars and from the roof areas. This visual survey provided a general understanding of existing conditions and permitted the investigators to select the range and extent of further investigation required.

The visual survey of the brick veneer revealed numerous bond separations between masonry units and mortar. The extent of bond separations also suggested poor workmanship and bedding of the mortar joints during installation. These separations, as well as cracks and voids in the mortar, allowed an increased amount of water to enter into the drainage cavity behind the masonry. Efflorescence, observed on the brick masonry at several isolated locations, primarily above the shelf angles, results from the deposition of soluble salts on the masonry surface and usually indicates water moving through the masonry. In addition, cracking and bulging were observed at shelf angle locations, and control joints had completely compressed in areas where there appeared to be blockage of the horizontal control joint.

Visual observation also revealed a widespread failure of sealant joints at window perimeters and curtain walls, including both adhesive and cohesive failures. A visual survey of the interior, performed in conjunction with the exterior survey, showed water damage to interior finishes at numerous windows, primarily at the ends of the sill members. Based on the results of the visual survey, locations were selected for close-up inspection, inspection openings, and water leakage testing.

CLOSE-UP INSPECTION
A close-up inspection was performed at representative locations from suspended scaffolding (swing stages) and personnel lifts. The close-up inspection provided the opportunity for inspection openings, field-testing, removal of samples, and implementation of a variety of diagnostic techniques. Evaluating the precast concrete units demanded nondestructive test methods, which included sounding techniques (tapping with a hammer) to identify delaminations and voids, and a metal detector survey to identify the presence and general location of metal plates. A boroscope, which uses a fiberoptic light source, was used to examine concealed conditions within the masonry wall through very small openings made in mortar joints. Sample removals included brick and mortar for laboratory testing, as discussed later in this section. During the metal detector survey for embedded brick ties, a lack of brick ties was detected near the floor lines. This allowed the masonry to displace outward at the shelf angles.

Inspection openings were performed at selected locations to permit examination of concealed conditions and to verify in situ construction. Inspection openings were made in the brick veneer at suspected sources of leakage and observed distress and at other locations of interest. Plan view drawings were provided for the overhead view to assist in locating areas for inspection. For example, inspection openings made at the shelf angle locations revealed that the through-wall flashing at the shelf angles consisted of paper-coated copper. The laminated sheet flashing was terminated or bent at the top of the angle, rather than extending to the face of the masonry. The flashing was not sealed down to the steel angle. Because the flashing terminated at the edge of the steel and was not sealed down, any water flowing off the end of the flashing could contact the steel angle.

An example of conditions revealed at inspection openings, the flashing at the window heads was found not to extend beyond the precut concrete lintel. Instead, flashing at these locations terminated approximately 2 in. beyond the window opening without dam. Water collected by this flashing flowed laterally and would drop onto the top of the masonry at the jamb, as observed during testing.

WATER LEAKAGE TESTING
A visual survey on the building interior was completed to identify evidence of moisture infiltration. Water spray testing was performed at selected exterior locations to evaluate the effectiveness of wall construction and windows to water leakage. Four test methods were used.

In spray rack testing, water is introduced against the surface of the masonry with a rack of nozzles calibrated to deliver water at a rate of 5 gallons per square foot per hour. The spray rack was built according to the ASTM E 1310, "Standard Test Method for Field Determination of Water Penetration for Insulated Windows, Curtain Walls, and Doors By Uniform or Cyclic Static Pressure." The test was performed under an applied Pressure Difference. The test was performed without an applied Pressure Difference. The test was performed without an applied Pressure Difference.
FLASHING AND END DAM LEAKAGE 15.33

WATER PENETRATED POORLY SEALED END DAM JOINT

ARROWS INDICATE WATER LEAKAGE PATHS

END DAM SET IN MASTIC (INSTALLED WITHOUT FASTENERS)

WATER LEAKAGE OCCURS AT UNSEALED/POORLY SEALED FASTENER PENETRATIONS

During spray rack testing of the window system, water leakage readily occurred at the sub sill. At locations where nozzle testing was performed to pinpoint leak locations, observation from the interior during the testing indicated that the leakage at the sill of the test windows was the result of water penetration at the sub sill, particularly at fastener penetrations and at incompletely sealed end dams.

Because of the need to confirm paths of water movement at the window sill, the window system was disassembled at several representative locations. The sub sill was found to be fastened to the wood blocking below, with screws that penetrate the sub sill; however, joint sealant was not present at some of these screw penetrations. Aluminum end dams were present at the terminations in the sub sill; however, the seals between the end dams and the sub sill were not complete in all areas. The end dams were not mechanically fastened to the sub sill. Also, sub sill fasteners penetrated the horizontal legs of the end dams at a number of locations.

Subsequently, laboratory testing of selected materials was performed to provide specific information about materials characteristics and causes of failure. For example, petrographic examination was performed on samples of precast concrete to confirm that no compositional problems appeared to be present. Petrographic studies involved a standardized microscopic examination of materials samples based on the methods outlined in ASTM C 856, "Petrographic Examination of Hardened Concrete," to evaluate the overall quality and soundness of the materials. Compositional analysis of the mortar using methods of ASTM C 1324, "Standard Test Method for Examination and Analysis of Hardened Masonry Mortar," including chemical methods to supplement petrographic examination, was performed to confirm that the mortar composition was in accordance with specification requirements. Absorption and saturation coefficient testing of brick was performed in accordance with ASTM C 216, "Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)."

Per ASTM C 216, five bricks were included in each test, and half of each brick was used as a test specimen. The results were obtained for the individual specimens and averages calculated, to compare the brick to requirements of ASTM C 216 performance. The information gathered through research and investigation was analyzed to determine the causes of observed distress and to inform decision making about appropriate repairs.
In this section, the concepts of research "through" design are addressed. These include design as research, site research, and building design research. A case study at the end of this discussion serves to illustrate these concepts in practice.

RESEARCH "THROUGH" DESIGN

The most used and least understood area of architectural research involves that which works "through" design, which engages design, itself, a form of research. Often in this work a "both-and" quality exists, as observed by Julia Robinson in her article "Architectural Research: Inocporating Myth and Science," in the Journal of Architectural Education (1990, pp. 20–32). Research "through" design, says Robinson,

- Acknowledges truth embodied in the context of natural settings.
- Resists existing knowledge as the foregone conclusion or solution.
- Allows inherent and contextual data to emerge unconstrained.
- Acquires holistic understanding by observing and absorbing real situations.

- Becomes embedded in complex, chaotic, contradictory situations.
- Accepts paradox without requiring its resolution.
- Uses dialectic conditions as a generative tension.
- Uses both atomistic and holistic perspectives.
- Allows both synchronic (at a time) and diachronic (across time) perspectives.
- Employs both intuitive and deductive logics.
- Recognizes omic (native, mythical) and etic (professional) explanations.
- Uses both direct experience and modeling of reality.
- Defines culture as the primary concept of interest and investigation.

A distinguishing characteristic of this notion of design-as-research occurs in its nonlinear, iterative, spiral-like way forward, from idea generation to visualization and realization to recording, peer review, and analysis, with points of reflection and readjustment along the way.

Research "through" design also tends to look, conceptually, like a schematic site or building plan, with waves of activity, clusters of advantages and disadvantages, and groups of possible solutions embracing the greatest number of issues and advantages.

Research "through" design takes different forms, depending on the project and the context, as defined here:

- Design research describes and analyzes existing designs with a known context, often in the form of comparative study of the designer's function, form, structure, and the way they were made.
- Typological research looks for types, forms, and categories of design within, for example, structure, technique, function, or context in different contexts.
- Design study involves making a design in a relatively well-known context of potential users, investors, available techniques, building materials, and political, ecological, and fiscal restrictions.
- Study of design generates knowledge and understanding by looking at the effects of varying both design solutions and their contexts.

These four forms of research "through" design also lie on a spectrum, with some more related to the intuitive and qualitative nature of art and others to the logical and quantitative nature of science.

**VISUAL MODEL OF THE RESEARCHER'S CREATIVE PROCESS**

15.34

ARCHITECTURAL RESEARCH

SCHEME 1: THE IN-BETWEEN REALM OF DESIGN

15.37

RESEARCH
THE SCIENCES
PRACTICE
THE ARTS

CREATIVITY
KNOWLEDGE
EXPERIENCE

LIMITATIONS AND BENEFITS GROUPED IN RELATION TO THREE SPECIFIC STAGES OF CREATIVE PROCESS: METHODS OF VISUALIZATION, METHODS OF TRANSFERRING IMAGERY BETWEEN MEDIA, AND METHODS OF RESOLVING CERAMIC ARTIFACTS (FLOATING POINTS RELATE TO EXTERNAL STAGES OF CREATIVE PROCESS: PEER REVIEW)

LIMITATIONS AND BENEFITS

"Research, instead, looks at what has been or what is, with the goal of evolving or discovering knowledge."

Architectural education, like practice, often overlaps both; discovering and conveying knowledge about what is or has been, as well as creating new ideas or insights into what might be.

According to Jack Green in Ways to Study and Research Urban, Architectural, and Technical Design (DUP Science, 2002), research "through" design follows certain predictable strategies:

- Decomposition: Because of the complexity of most design projects, this strategy involves decomposing the project; that is, it is taken apart and subsequently reassembled so that items of importance can be isolated and developed further in detail. This allows the designer to look at parts or combinations of parts in relation to the whole, recognizing levels of priority and room for variation.

- Variation: By systematically organizing or structuring a project, designers can begin to see compositional variations, based on dimensions, rhythms, proportions, subdivisions, connections, materials, and colors, to name a few. Often, different variations based on some identifiable theme or motif are worked out, compared, and evaluated.

- Visualization: Possible design solutions have to be made visible for the benefit of the designer or design team and for the other factors involved. Drawings and models are the primary "languages" of design communication, also forming a "laboratory" involving (de)composition, selection, and variation. This visualization creates impressions of the effects of potential design decisions, which makes choices accessible.

- Reference study: The study of precedents can form a project library, allowing for comparison with similar types of projects and solutions. Findings are not translated literally in the design at hand, but primarily allow for reflection concerning the merits of intermediate design solutions.

Another way of thinking about design as research is the comparison of designs, both the designed object and the context. Taek de Jong and Leen van Duin, in Ways to Study and Research Urban,
**PROJECT GOALS AND OBJECTIVES**


---

**NOTES**

15.39a. Legend refers to that which takes form, be it a material (concrete, brick) or an element (road, green space).
15.39b. Form involves the joining, distribution, or layout of the material or space in or around the material.
15.39c. Structure is the manner in which composing parts remain as a whole, the complication of separations and connections in a joined whole.
15.39d. Function refers to any external action, the activities that occur in or around a design.
15.39e. Intention relates to the idea or goal of the design and to its meaning.
IMPACT ON ENVIRONMENTAL AND SOCIAL/CULTURAL RESOURCES

13.41

IMPACT ON PHYSICAL RESOURCES

13.42

DESIGN RESEARCH
ARCHITECTURAL RESEARCH 975
IMPACT ON SOCIAL RESOURCES
15.43

ENVIRONMENTAL ANALYSIS PROCESS CHART
15.44
SCREENING OF PROSPECTIVE SITES

1. Conduct site investigations to verify findings from screening.
2. Confirm off-site relationships.
3. Develop conceptual layouts for each candidate.
4. Develop cost estimate for each candidate.
5. Review public agency and special interest group concerns and preferences.
6. Establish framework and criteria for site evaluation process.
7. Summarize candidate sites and their characteristics (unweighted).
8. Refine data; collect additional data as necessary.
9. Is site ranking desirable?
   a. Yes: Determine weighting scale to be applied to site evaluation criteria.
   b. No: Determine relative importance of each criterion.
10. Weigh suitability of each candidate site relative to satisfaction of each criterion.
11. Compare scores; display results in comparative site evaluation matrix.
12. Rank sites according to total weighted scores.
13. Final decision is confirmed; reviewed by political body, regulatory agency, or public vote.

*KEY DECISION-MAKING STEPS
PROSPECTIVE SITE PROCESS CHART


STATEWIDE

Define Goals and Product of Screening Effort

Identify and Resolve Critical Issues; Set Policy

Identify Data Requirements (Screening Factors)

Design Data Base and Data Processing Tools

Input from State Agencies on Critical Issues

Hold Public Workshops to Examine Issues and Screening Factors

Establish Technical Advisory Committee
- Federal Agencies
- State Agencies
- Regional Agencies

Conduct Public Participation Plan
- Citizen Division
- Public Advisor

Define Goals and Objectives of Public Participation
- Commission
- Staff
PUBLIC PARTICIPATION (continued)

15.47

Design research can occur, as well, in a workshop setting, either to address a particular building project or an issue that might emerge from previous research.

Design research focused on the built artifact itself follows a parallel set of processes. An individual designer or a project team can conduct research on a particular artifact. Research can also look at how different processes or different interpretations lead to the best artifact.

**DESIGN-DRIVEN RESEARCH**

<table>
<thead>
<tr>
<th>Cluster 1: Design Activity Driven Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub Cluster 1A: Design Process Driven Research</td>
</tr>
<tr>
<td>1: Individual Process Based Research</td>
</tr>
<tr>
<td>2: Thematic Process Based Research</td>
</tr>
<tr>
<td>Sub Cluster 1B: Design(ERly) Workshop Driven Research</td>
</tr>
<tr>
<td>3: Design Workshop Based Research</td>
</tr>
<tr>
<td>4: Designerly Workshop Based Research</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cluster 2: Design Artifact Driven Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub Cluster 2A: Design Result Driven Research</td>
</tr>
<tr>
<td>5: Individual Result Based Research</td>
</tr>
<tr>
<td>6: Comparative Result Based Research</td>
</tr>
<tr>
<td>Sub Cluster 2B: Design(ERly) Enquiry Driven Research</td>
</tr>
<tr>
<td>7: Design Data Comparison Based Research</td>
</tr>
<tr>
<td>8: Designerly Interpretation Based Research</td>
</tr>
</tbody>
</table>
**ACTIVITY-DRIVEN RESEARCH**

15.49


**WORKSHOP SETTING FOR DESIGN RESEARCH**

15.59


**ARTIFACT-DRIVEN RESEARCH**

15.51

The building delivery process follows a range of options as well. (According to John Roberts in The Building Site (Wiley, 1983), the traditional design and construction delivery process typically happens as shown in Figure 15.53. When the owner is also the contractor, the relationship changes accordingly; this is shown in Figure 15.54. A range of design/build alternatives also exist, of which the typical arrangement takes the form shown in Figure 15.55.)

Example of design as a form of research is the development of an active, pressure-equilized, double-skin curtain wall that Gens Timberlake Associates (GTA) describe in the following case study.

**BUILDING DELIVERY PROCESS**

15.53

---

**OWNER AS CONTRACTOR**

15.54
CASE STUDY: CURTAIN WALL DESIGN

Levine Hall, completed in 2003 for the School of Engineering and Applied Science at the University of Pennsylvania, Philadelphia, Pennsylvania, houses offices, labs and meeting space for the Computer and Information Science Department. The site of Levine Hall was a former service and parking zone located at the center of the engineering school’s precinct. The new building provides 46,000 sq ft of space on six floors, forming a quadrangle with existing buildings around a landscaped interior courtyard and providing internal north-south connections between two existing buildings of very different architectural character (built in 1968 and 1967) and floor-to-floor heights.

The university requested a building that would provide long-term flexibility in the use and arrangement of space. Accordingly, Levine Hall is an “academic loft” with 14-ft floor-to-ceiling heights and exposed, accessible building systems, post-tensioned flat-plate concrete structure, fully glazed exterior walls, and partially glazed interior partitions. At ground level, a new campus walk leads directly to a double-height entry lobby with views through to the courtyard beyond. Corridors connecting adjacent buildings run along the west facade at the third and fourth floors, providing views out to the campus while enlivening the facade with views of people within.

Faculty offices are located at the perimeter of the building to the east, west, and south, with abundant natural light and views. Floor lounges with views of the courtyard are provided throughout the building, allowing places for meeting and orientation at each level.

The exterior is articulated as a glazed pavilion, presenting luminous, transparent facades to the campus. This strategy allows daylight to be maximized on a dense, urban site, while also allowing visual interconnection between the life of the campus and activity within the building. The facades are constructed using ventilated double-skin curtain wall technology in a composition of transparent and translucent glass—the first use of this system in the United States.

APPROACH

The initial phase of design work consisted of a planning study for the proposed computer science building and a future bioengineering laboratory. Given the complexity of the site, the study focused on campus planning issues and established a footprint and massing proposal for the building, with specifics of program to be explored later. Early in schematic design, two key issues emerged as priorities: (1) the character and articulation of exterior walls and (2) the quality of faculty workplaces.

The location of the building in the center of a block ringed by the campus signature deep-red brick buildings suggested the possibility of glass as a counterpoint and as a way to maximize daylight on the site. The use of the building to house advanced technology research also suggested glass as a means of expressing contemporary building technology. The University Facilities and Planning department and the School of Engineering and users were intrigued by this approach, provided interior comfort and energy efficiency could be achieved.

To meet these goals, KTA began a comprehensive analysis of the wall’s components, and potential manufacturers to ensure a broad review of the performance and technology of aluminum and glass curtain walls throughout the United States, Europe, and Asia. The development of curtain wall technology has proceeded along divergent courses in response to differing economies, regulatory requirements, and engineering and manufacturing practices.

The first level of investigation examined different approaches to advanced glazing systems of 18 manufacturers, recording findings in a series of detailed matrices that compared characteristics of conventional and high-performance curtain-wall technology. Criteria for comparison included the energy code, thermal performance, energy consumption, availability, constructability, maintainability, first cost, service life, and more subjective criteria such as comfort and appearance. Early on in these discussions, KTA’s energy consultant, Donald Fowler, suggested active curtain wall technology as a way to reconcile large expanses of glass with stringent new energy codes and occupant-comfort requirements (the inadequacies of the curtain wall in the adjacent 1960s lab building were well-known by its occupants).

The second level of investigation focused on the principles of double-skin curtain wall systems and refinement of performance parameters to address the university’s requirements for a fully glazed wall. Kieran Timberlake worked with environmental engineers and modeled performance using computer software to develop an energy-efficient system, as well as numerous studies of physical models, and fully on site. The process of installing the curtain wall systems as building components was complicated by the potential for mass customizations enabled by the production process.

The wall design incorporates a ventilated curtain wall system composed of an external insulated glass unit (IGU), an internal ventilated cavity in between, and an air outlet at the head of the glazing frame; it acts as a plenum through which room return air is circulated and exhausted by the HVAC system.

Integrated electronics control motorized window blinds located on the facade; these reflect some of the solar radiation incident on the facade back through the external glass and absorb the remaining radiation, releasing it as heat into the cavity space. The primary function of solar heat control is achieved by ventilating the air supplied through the cavity at room temperature, while the internal glass unit surface temperature is within 1° to 2° of room temperature, eliminating surface radiation effects and improving occupant comfort. The extracted heat is used by a heat exchange system to offset building heating and cooling loads, eliminating the need for perimeter radiation for winter heating. The blinds are fully adjustable, allowing for full shading or vision; they are also unobtrusive to the external appearance of the building and require minimal maintenance.

The system is built entirely at the factory on prilled aluminum frames. These complete panels are erected and joined onsite using factory-installed gaskets, eliminating the need for manual sealant application. The system was technically complex, and of the manufacturers investigated, only one, Pemasteelsa, proved capable of building the wall. The university was interested, but skeptical; it was less than enthusiastic about paying 25 percent more than a standard curtain wall first cost for a system with energy-saving benefits at a time when the price of a gallon of gasoline was $1.15. Moreover, the university was not interested in proprietary products and had concerns about a European system unknown by prior use in the United States.

Consequently, additional research was undertaken to determine the system’s value, analyzing the trade-offs over standard curtain wall construction in terms of heating and cooling loads, life-cycle costs, acoustic properties, and long-term value. This enabled the development of a detailed, performance-based, nonproprietary specification and detailing system. Even though the economic and performance analysis built support for the active curtain wall, there was also concern for the additional aesthetic approach sensitive to the historic campus. By knitting the curtain wall with the brick, a consistent detail was created wherein the new glass building joins the existing masonry, interfacing in transparent and opaque wall systems. This moment of negotiation between the adjoining early twentieth-century structures and the new twenty-first-century glass curtain wall created a detail that allowed the building to fully embrace the design.

The units came to the site pretested and preassembled, allowing efficient use of limited laydown space. A Pemasteelsa project manager was on-site for the initial phases of the curtain wall erection; management was on-site for the initial phases of the curtain wall erection; management was on-site for the initial phases of the curtain wall erection; management was on-site for the initial phases of the curtain wall erection; management was on-site for the initial phases of the curtain wall erection; management was on-site for the initial phases of the curtain wall erection.
<table>
<thead>
<tr>
<th>MANUFACTURER</th>
<th>CONVENTIONAL</th>
<th>STRUCTURAL SILICONE GLAZING</th>
<th>HIGH TECH ASIA</th>
<th>HIGH TECH EUROPE</th>
<th>POINT SUPPORT GLAZING</th>
<th>DOUBLE SKIN FACADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>WISCONSIN METALS, WISCONSIN</td>
<td>STRUCTURAL SILICONE ON</td>
<td>HORIZONTAL RIBBON WINDOW</td>
<td>WISCONSIN METALS, WISCONSIN</td>
<td>WISCONSIN METALS</td>
<td>JAPAN</td>
<td>JAPAN</td>
</tr>
<tr>
<td>ZEUS</td>
<td>2'-0&quot; 3'-0&quot; * 3'-0&quot; SIGHTLINES</td>
<td>GRAPHIC</td>
<td>SIGHTLINES</td>
<td>GRAPHIC</td>
<td>2'-0&quot; 3'-0&quot; * 3'-0&quot; SIGHTLINES</td>
<td>GRAPHIC</td>
</tr>
<tr>
<td>ZEUS</td>
<td>GRID WITH EXPOSED METAL LUMINOSITY</td>
<td>VERTICAL &amp; HORIZONTAL</td>
<td>SIGHTLINES</td>
<td>VERTICAL &amp; HORIZONTAL</td>
<td>SIGHTLINES</td>
<td>VERTICAL &amp; HORIZONTAL</td>
</tr>
<tr>
<td>ZEUS</td>
<td>ALL GLASS &amp; MONOLITHIC APPEARANCE</td>
<td>HORIZONTAL RIBBON WINDOW</td>
<td>ALL GLASS &amp; MONOLITHIC APPEARANCE</td>
<td>HORIZONTAL RIBBON WINDOW</td>
<td>ALL GLASS &amp; MONOLITHIC APPEARANCE</td>
<td>HORIZONTAL RIBBON WINDOW</td>
</tr>
<tr>
<td>ZEUS</td>
<td>GLASS BONDED TO METAL FRAME WITHOUT A PRESSURE BAR</td>
<td>GLASS BONDED TO METAL FRAME</td>
<td>GLASS BONDED TO METAL FRAME</td>
<td>GLASS BONDED TO METAL FRAME</td>
<td>GLASS BONDED TO METAL FRAME</td>
<td>GLASS BONDED TO METAL FRAME</td>
</tr>
<tr>
<td>ZEUS</td>
<td>THERMAL BREAK TECHNOLOGY USES THERMOPOLYESTERS</td>
<td>THERMAL BREAK TECHNOLOGY USES THERMOPOLYESTERS</td>
<td>THERMAL BREAK TECHNOLOGY USES THERMOPOLYESTERS</td>
<td>THERMAL BREAK TECHNOLOGY USES THERMOPOLYESTERS</td>
<td>THERMAL BREAK TECHNOLOGY USES THERMOPOLYESTERS</td>
<td>THERMAL BREAK TECHNOLOGY USES THERMOPOLYESTERS</td>
</tr>
<tr>
<td>ZEUS</td>
<td>GLAZING VIA INTERIOR OR EXTERIOR</td>
<td>GLAZING VIA INTERIOR OR EXTERIOR</td>
<td>GLAZING VIA INTERIOR OR EXTERIOR</td>
<td>GLAZING VIA INTERIOR OR EXTERIOR</td>
<td>GLAZING VIA INTERIOR OR EXTERIOR</td>
<td>GLAZING VIA INTERIOR OR EXTERIOR</td>
</tr>
</tbody>
</table>

**FINISH-METAL FACADE**

**USED IN LOW, MILD, & HIGH RISE APPLICATIONS**

**TYPICAL LEAD TIME**

**CLASSIFICATION OF WALL SYSTEMS**

<table>
<thead>
<tr>
<th>LOW END: $500-1000/5F</th>
<th>MED END: $750-1000/5F</th>
<th>HIGH END: $1000-1500/5F</th>
</tr>
</thead>
</table>

**NOTES**

1. ALL THE SYSTEMS ILLUSTRATED ABOVE INCORPORATE THE RAINSCREEN PRESSURE EQUALIZED WALL DESIGN, THE ONLY EXCEPTIONS ARE THE 4-SIDED SSG AND POINT SUPPORT GLASS SYSTEMS, WHICH RELY ON THE SEALANT BETWEEN EXTERIOR GLASS LITES TO KEEP MOISTURE OUT.

2. OF THE FOUR SYSTEMS SHOWN AT LEFT, THE STACK SYSTEM IS THE MOST COMMONLY EMPLOYED INSTALLATION METHOD FOR CONVENTIONAL SYSTEMS, THE HIGH TECH SYSTEMS ARE EXCLUSIVELY ASSEMBLED USING THE UNITIZED SYSTEM.

3. GLAZING TYPES HAVE A SIGNIFICANT EFFECT ON THE APPEARANCE AND THERMAL PERFORMANCE OF A CURTAIN WALL, RANGING FROM BRIGHTLY REFLECTIVE (MIRRORS) TO COMPLETELY TRANSPARENT AS VIEWED FROM THE EXTERIOR.