"Reverse Architecting": A Case Study Approach Toward Comprehensive Design Learning

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This paper addresses the session theme of how building case studies can be "successfully integrated into the curriculum of professional architectural education" in the specific context of comprehensive design. The basic argument is that analytical methods of building case studies are a necessary educational complement to the synthetic approach of design studio. The term "reverse architecting" is coined here to suggest the same mode of thought associated with "reverse engineering," i.e., working backwards through the original development cycle by starting from an exemplary end product and reinventing the process of discovery.

Rationale

Comprehensive design has become an explicit goal of upper level architectural education. This goal is operationalized in the U.S. by the National Architectural Accrediting Board (NAAB) as the "ability to produce a comprehensive architectural project based on a building program and site that includes development of programmed spaces demonstrating an understanding of structural and environmental systems, building envelope systems, life-safety provisions, wall sections and building assemblies and the principles of sustainability.[1]

Coevolving with comprehensive design is the study of building systems integration. This goal is also operationalized by NAAB as the "ability to assess, select, and conceptually integrate structural systems, building envelope systems, environmental systems, life-safety systems, and building service systems into building design." This parallel emergence of comprehensive design and systems integration as certifiably essential learning objectives reflects growing recognition of how complex architectural design has become. It also demonstrates how necessary it is to equip students with holistic understandings of the means by which architects deal with this complexity. The ultimate goal is to embrace this complexity in meaningful ways that enrich design.

This present work is derived from the pedagogical development of a capstone undergraduate seminar course in building systems integration. The discussion includes student learning objectives of that course as well as the case study methods of its teaching. Special emphasis will be made in showing how the case study method can be utilized in a reverse mode of what is generally practiced in design studio.

Background

The case study method in architecture is commonly used as an episodic research tool. The usual ends of such studies are that of precedent buildings, typological issues, or technical approaches. Case studies of this sort are seldom comprehensive however, and typically serve a narrow focus that satisfies the bias one had before investigating. These sorts of case studies are perhaps informative, but may play a negative role by reducing the result to that which reinforces preconceptions of style or other reductive simplifications. What is often lacking is a specific focus on the comprehensive or "deep" case study that tells the whole complicated story in a way that captures the true complexity and unique essence of a particular exemplary work of architecture.

Case Study Issues

Case study literature in architecture is well established as a mode of investigation and interpretive analysis.[2,3,4,5,6,7,8,9,10] More recently, this method has become increasingly regarded as a sort of clinical database such as that of the case in law or medicine.[11,12,13,14,15] This present paper further expands on the architectural case study method as an explicit means of design learning. The following sections deal with specific issues of that learning: holistic design, systems thinking, and complex problem space.

Holistic Perspective on Design Creativity

Creativity may be defined as work which is both novel and appropriate. Creativity in architecture is therefore, like any other field, dependent on having domain knowledge with which to fashion designs that are equal parts novel and appropriate. In architecture this knowledge domain broadly consists of history, theory, criticism, human factors, technology, and practice issues. The traditional role of design studio then, is conceptually that of assimilating those requisite understandings into new ideas and then operationalizing those abstract ideas into real world forms, spaces, and materials. This is an oversimplification of course, and design studio has other significant objectives dealing with aesthetic and sublime interpretations of the work it produces. The point here however, is that studio is a synthetic approach to comprehensive application of architectural knowledge. This comprehensive scope should capture much of what is essential and celebrated in architecture: It should feature open ended problems, foster complex integrated solutions, and produce propositions that engender human significance.

Speaking in general terms, the difficulty with studio as the sole comprehensive basis of architectural education is that synthetic design exercises are necessarily reductive and that this reduction eliminates much of what makes the work of the architect so valuable. In short, it takes a team of experts working together over a period of a year or so to produce a comprehensive design solution. It is simply not possible for one student working alone for six or eight weeks to produce anything but a propositional beginning of an integrated building.[16]

Design studio is of course, not intended to produce finished buildings or students who are prepared to design such works on their own. Rather, studio is dominated by goals related to sublime issues of human significance. Studio is still however, usually taken as the assimilation point of the entire architecture curriculum. To accomplish this assimilation the design studio necessarily omits many complex factors… factors that positively impact design in the full context of professional practice. These omissions are, generally speaking, measures of accountability that are untenable to the framework, resources, and general goals of design studio teaching. To wit:

- Programming—studio problems are often given as predetermined space lists or other prefigured requirements with little opportunity for students to define the problem for themselves or to research what the situation demands

- Conflicting stakeholders—most studio work is not accountable to real clients or the constituent interests of various users groups with different interests and criteria

- Critical technical issues—generative aspects of inherent, contextual or design intention; performance accountability

- Systems—selection, configuration, deployment, and integration of site, structure, envelope, services, and interior systems

- Budget—first cost, project budgeting, operation costs, life cycle costs…

- Agility—expansion, adaptation, constructability, serviceability, flexibility, durability…

- Operation—maintenance, energy, productivity, commissioning, re-commissioning, occupancy, postoccupancy…

It would be wrong to expect design studio education to broadly address these factors. Despite the comprehensive and central role of design studio, it is clearly not intended to operate as a miniature professional practice turning out complete buildings in the real world setting. Studio, for all these reasons, is synthetic but reductive.

In light of the mission goals, namely comprehensive design and systems integration, it should prove both complementary and essential to provide a parallel track of comprehensive design investigation based on the analytical approach of case study. Case study analysis provides access to those complexities the synthetic track of studio must omit. Further, the expansive and synthetic "why not" thinking of design studio, exactly complements the contractive and analytical "so what" thinking of case studies. Together they form hermeneutic cycles of iteratively observing, interpretation, postulating, trying, evaluating, then reinterpreting the problem and repeating the cycle. Design reasoning that continually oscillates in this way is clearly more complex, comprehensive, integrated, and hence, innately architectural.

Systems Thinking

The term "system" here, is defined as the complex order and interrelation of parts that act in dynamic rather than mechanistic ways. By way of example, a tree farm is a machine while a forest is a system. A Frankenstein is a machine that never achieves complex order. The human mind is a self-ordering system that emerges from complex interaction.

Two levels of systems thinking should be discussed. The first is that of systems as complex problems. The design space or problem space of architecture is an example of such deeply interrelated factors and dynamic response. The second level of systems thinking is that of building systems themselves and the continuum of their conception from mundane hardware at one end to integrated components of animated building designs at the other.

First, the architectural design space has been treated as a complex system or "wicked problem" due to its indefinite beginning and ending states, the impossibility of having complete knowledge of the design requirements, and other such indeterminate characteristics.[17] In this current discussion, the notion of wicked problems suggests a complex systems approach to the formulation and execution of architectural projects. This is not to suggest that architectural design activity itself be defined as a systems problem, only that the formulation of the design space within which the designer operates be considered as indeterminate. At heart here is the issue of capturing the true complexity at the essence of a complete architectural project rather than forsake that complex essence in the effort to work synthetically but reductively in studio.

Secondly, the idea of a system has become so generic in architectural parlance that it is usually reduced to a meaningless reference to hardware. This reduction is a handy way of not having to list all of the constituent parts that make up the plumbing system, but it does sacrifice the deeper and more architectural notion of what a system really is. Steven Groák referred to this deeper notion in his as a set of organized flows: "In the most general formulation, taking buildings and their surroundings as open systems, we can describe buildings as affected by receiving, filtering, storing, processing, dispatching, repelling or discarding… " The flows he is referring to include people, information, materials, energy, light, air, and all the hosts of flows that buildings manifest.[18]

Tying the two levels of systems thinking together then, it is possible to describe architectural systems on five levels:

- Systems as Hardware—generic use of "system" to describe building components, such as the plumbing system or the HVAC system.

- Systems as Prototype—a collection of elements that form what Norberg-Schulz calls a "characteristic way of organizing architectural totalities." The high-rise typology is, for example, characterized by steel frame structure, curtain wall envelope, and elevator circulation

- Systems as Grammar—every genre of architecture has a grammar of interaction among building components. In High-Tech thinking for example, systems are used to visually express the servicing of buildings.

- Systems as Species—taken in an anatomical sense, the structure, envelope, ventilation, plumbing, and electrical systems of a building can be compared to the skeleton, skin, lungs, digestion, blood flow, and nervous systems of living organisms. A section through a building is thus much like a vivisection of an animal.

- Systems as Flow—a system is a set of organized flows.[19] Flow can be the channeling of material, information or energy. A structural system is thus the organized flow of forces through a network of members to carry loads to the ground and produce static equilibrium. All architectural systems can be thought of as organized flow in this way, and their components conceptualized as filters, barriers, switches, capacitors, conduits and reservoirs. As a cross-reference, note that cybernetic systems have teleological intent and animating self-correcting feedback.

Capturing Complexity and Systems Thinking

To capture the complexity and unique essence of a complete work of architecture, one needs to either experience the real world conduct of the project, or encounter a narrative that faithfully records the decisions taken along with the reasons underlying them. The narrative case study has the obvious advantage of showing where the dead end explorations were without having to walk them. Thus, while the actual stakeholder conflicts, budget considerations, construction strategies and so forth can be included in the case study, these factors can still enrich the architectural project and capture its unique essence.

In the educational design studio however, this narrative is too engrossing, too detailed, and too impossibly sophisticated to be investigated and then embed in a design problem. The most background that might be considered would be a precedent study or two, a trip to the site, and a visit with a consultant. In those cases however, the selection of information and the exclusion of other data are frequently biased toward a preconceived approach to the physical design. Such bias is human; it is however always reductive in prefiguring the solution and in forcing richly complex problems into simplistic frameworks.

This allegation of reductive tendencies is not a critique of the design studio; it is a simple result of a synthetic process set in a limited timeframe with limited resources and limited knowledge. This is a necessary set of conditions in a design studio, but it should not be a necessary restriction on student understanding of how works of architecture happen, how complex the problems are to identify and resolve, or how design is animated by this complexity.

Case Study Methods

Overview

As presented in the Rationale section above, this paper is based on the development of a capstone technology course for upper level undergraduate architecture students. As comprehensive design learning, the case study method is used in this course to literally “reverse architect” the building design.

The following sections describe the weekly assignment objectives of a case study course in building systems integration. The delivery of these assignments is couched in a paradigm shown in Fig 1.

As background, students are asked to take ownership of the case study project and play the role of project design architect. This involves a mental level of engagement where the student is trying to recreate the architect’s thinking, their need for information at different phases of the work, the constant transformation of factual data into useful information, the formulation of design intent, and the application of such information and intentions to design decisions.

Because students start with a completed building solution, the documentation research for project data is minimized. Missing information becomes part of how students read the building to deduct and estimate undocumented information. The rediscovery of the comprehensive design process then becomes the primary case study task.

Given the exemplar quality of a self-selected and well-chosen case study building, students can continually validate their own design thinking against that of a successful built work. They can also compare their own decision making to the criteria of accountability that the case study building had to satisfy. This built-in feedback is another of the case study methods complements to the role of comprehensive design studios.

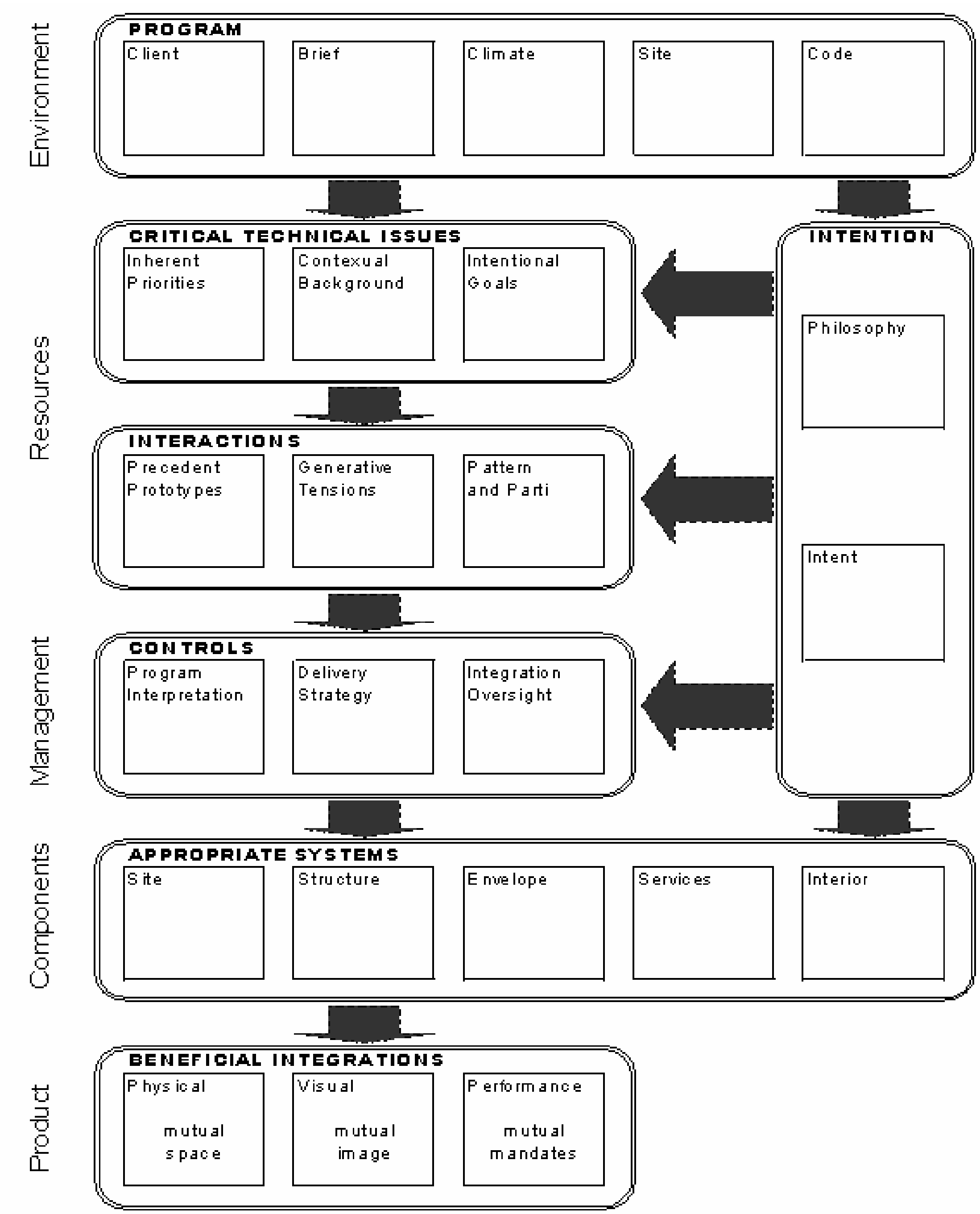

Fig. 1. Systems integration model of the architectural case study analysis

Project Determinates

The initial sections of the case study work are neither analytical nor synthetic. Instead, the idea is to build intimate familiarity with the client, their view of the project, budget considerations, the site, relevant codes, and other determinates.

Typology and Precedent

Diagram the organizing geometry, "parti," shapes, forms, or other key ordering devices of the building. Compare it to the characteristic solutions commonly used for this or similar building types. Categorize the general approaches for organizing design in this building typology. Describe the general critical issues related to this typology and compile a list of common requirements and planning guidelines.

Illustrate this section with the most notable "exemplar" works that illustrate the various categories. See what architectural precedents the architect may have used.

Performance Specifications

Consider the empirical realities and numerical magnitudes as they are appropriate to the building. Extend these ratings to elements of the design, e.g., windows have many numerical ratings such as, SC, VLT, SHGF, SHGC, TL, STC...

Extend these ratings to the project's various room types or user activities, i.e., auditoriums have critical acoustical criteria. Extend the ratings to cover issues of the architectural intention

Climate Analysis

Interpret and evaluate the relation of climate to building and the potential of passive climate systems, daylighting, the need for shading, and the seasonal patterns of change. Describe the relative climatic priorities and ranked order of climatic design possibilities.

Interpret the macro and meso character of the climate, important distinctions, and seasonal character. Interpret these findings to the building program and to thermal metabolism of the building.

Site Analysis

Interpret context of the site as a microclimate of the regional climate. Consider the site as the architect found it before the building was designed, and evaluate how its potentials were ultimately utilized.

Structural Analysis

Include framing plans, tributary load analysis, and description of structural action. Numerical approximations are required. Describe major spans and how they are carried. Incorporate values from the Performance Specifications.

Daylighting Analysis

Include numerical analysis of daylight levels in the completed building and compare those to the ideal levels. Discuss seasonal variation and how it is accounted for in the design. Incorporate values from the Performance Specifications.

What interior and exterior design elements contribute to daylight integration as a reflector, lens, or louver? How are these elements integrated into the architecture? Pay particular attention to glass types and shading.

Interior Systems

Draw on building plan and sections to illustrate this section. Numerically evaluate egress requirements and compare them to the completed design. Incorporate values from the Performance Specifications. Examine interior zoning for thermal, lighting, and acoustical organization. Describe fittings, fixtures, furnishings and specialties. Look at fire safety and suppression.

Envelope Systems

Envelope Analysis- Format: think of the envelope as the moderator of inside and outside conditions. Diagram its actions and evaluate its relative performance. Incorporate values from the Performance Specifications.

MEP Analysis

Identify the integration of all schemes and hardware. Locate the systems and distribution components (like ducts) on plans and sections. Incorporate values from the Performance Specifications.

How are MEP systems selected, configured, deployed, and related to other systems: hvac, electric, plumbing, controls, thermal zoning, capacity, central or distributed systems, plant, delivery, distribution, control, thermal storage, energy conservation, indoor air quality, ventilation, fixtures, specialties, hardware, etc. ?

Identify the components and strategies of the HVAC system and their placement in the building. Where are the plant, delivery, and distribution devices and how are they configured (VAV, package systems, cooling towers…).

Locate and identify the plant equipment (boiler, chiller, cooling tower, or other particular elements used). Locate and identify the distribution system(s) between the plant and the delivery system fans (2-pipe, 3-pipe, 4-pipe, dual duct, VAV, multizone…). Locate and identify the delivery system, usually consisting of supply and return air ducts.

Discuss any special circumstances related to controls if they are known (thermostats, automated control…).

Locate and identify thermal storage components, either in the mass of the structure or in other media such as off peak generation of cold water or ice.

Formal Analysis

Analyze the formal composition and physical design (materiality and spatial characteristics) of the case study building. Use diagrams and sketches to illustrate.

How is the architectural intention expressed? What makes the building and its ideas legible? How are technical visual integration and artistic formal issues brought together? Why?

Anatomical Analysis

Construct a large scale section through a generic or idealized room. Use this drawing to capture the interaction of all the building systems and relevant site systems. Use lots of notes to communicate what can't be readily drawn.

Think of the anatomical section as the vivisection of an animal. How are the systems integrated in ways that bring the building to life, or animate it in some way?

At all levels of systems thinking, how do the systems interact? How does this reflect design intent?

Strategic Analysis

Analyze the strategic design characteristics of the case study as it embodies intelligence. In many ways, strategic design relates to the critical technical issues of a program.

How do physical design and strategic design combine to produce beauty? How do they mutually express architectural intent?

Functional practicality, economy of means and costs, and efficiency of time and effort are basic elements of architectural programming

Constructability is a long ennobled aspect of design. The articulation of structure is a common physical design expression of this, but the idea of constructability is by itself a strategic one.

Serviceability is a newer form of constructability and was probably originated in Louis Kahn's notion of served and servant spaces. How is servicing accomplished intelligently and why were the particular strategies chosen?

Agility relates to expansion, adaptation, flexibility, churn, and a host of other terms that deal with the means by which a building is designed to change in pace with its evolving use and occupancy. How agile is the case study building?

Sustainability is the most important and influential idea to be institutionalized in the practice of architecture in the last fifty years, since the advent of practical air-conditioning. Most design discussion has confused the strategic aspects of sustainability with its physical design implications. Sustainability also captures the notion of natural teleology and complex systems.

Case Study Manual

A thirty-three page case study manual used in the referenced course is available by request from the author at no charge. It contains course material and reference to specific case study resources.

Endnotes

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[18] Groak, Steven. 1992. *The idea of building: thought and action in the design and production of buildings.* London: E & FN Spon. Where Groák uses the networking terms of conduits, capacitors, and reservoirs; Christian Norberg Schultz described "filters, barriers, and switches." John Tilman Lyle later added the principle of "using form to channel flow" as an explicit mandate of sustainable design.

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