CAN WE TEACH LEAN CONSTRUCTION METHODS IN SCHOOLS OF ARCHITECTURE?

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ABSTRACT

Traditionally, schools of architecture are not great laboratories to explore the collaborative processes and teamwork that are essential to integrated design and delivery practices as exemplified by Lean Construction. The pre-eminence of the "hero-architect" in the design studio is in direct conflict with methods that can reduce risk and improve the efficiency of the design and construction delivery process. Risk? Efficiency? Delivery Process? … not to mention Cost Control, Schedule and Constructability, are foreign concepts to the predominant design studio culture.

Integrated practices and integrated project delivery are clearly "hot" topics in the design and construction industry today. They are a response to pressures from building owners and developers for more efficient and predictable processes for designing and constructing buildings, and to the increasing availability of advanced digital technologies such as Building Information Modeling (BIM).

Can an institutionally enshrined resistance to this new approach to design and delivery in the Academy be overcome? Should it? These are the questions that institutions that teach design and construction practices are wrestling with all over the country. This paper addresses an approach that allows interdisciplinary teams to apply the basic elements of Integrated Practice and Lean Construction to a real world case study that is designed using a common Building Information Model.

KEYWORDS

architecture, integrated project delivery, lean construction, collaboration, construction management, action learning, target cost

INTRODUCTION

Schools of architecture are known for their "studio" culture with a strong emphasis on originality and individuality. Thus, historically they have not been fertile ground for

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an exploration of the collaborative processes and teamwork that are essential to integrated design and delivery (IPD) practices as exemplified by Lean Construction. Students learn about, admire, and follow the exploits of a cadre of "hero-architects" in the design studio and in their coursework. Many of these "heroes" are known for their unassailable egos and uncompromising attitudes about "their" projects.

This attitude is not compatible with emerging design and construction processes that reduce risk and improve the efficiency of the building in an increasingly complex and litigious world. Concepts such as "risk", "efficiency", "cooperation", not to mention concerns about costs, schedule, and logistics, have traditionally been foreign to the predominant design studio culture in Schools of Architecture.

However, over the past decade the academic culture has been changing in response to pressure from the design and construction professions and the exigencies of the "real world". Integrated Project Design and Delivery (IPD), as defined by both the American Institute of Architects (AIA) and the Lean Construction Institute (LCI), involves a primary focus on a project's objectives, and realignment of an interdisciplinary team consisting of the project's designers, constructors, and owners.

IPD and Lean Construction are clearly "hot" topics in the design and construction industry today. They are a response to pressures from building owners and developers who have been frustrated by an industry that has not seen increased productivity for almost half a century. The consumers of building design and construction are insisting on efficient and predictable processes for the delivery of building projects, and the industry is responding with integrated and collaborative methods that are changing the way we design and build.

The other recent change in both professional and academic circles is the continued development and sophistication of advanced digital technologies, particularly with respect to three-dimensional modelling. Designers and constructors are now able to create and share smart, virtual models that contain all the elements of a proposed project, including information that can be used to establish costs, construction sequencing, and scheduling parameters. The nomenclature of this virtual model has been universally accepted as the Building Information Model (BIM). Thus the world of construction is changing with new methodologies like IPD and LC, which can now be enabled by a highly intelligent tool: BIM.

In contrast to the traditional design and construction methodology, the integrated approach promotes early and active collaboration among owners, designers, constructors, along with planners, landscape designers, consulting engineers, and other members of the design and construction team, including input from subcontractors, major suppliers, and fabricators.

How can Schools of Architecture respond to this changing paradigm? Can we overcome a deep-seated resistance to collaborative planning and design? Can we respond to the construction industry's call for prepared, skilled graduate architects who can "hit the ground running"? Can we begin to simulate the essential elements of this new approach to design and construction in coursework for advanced students? In an academic setting can we explore…?

- Open and continuous information sharing and team collaboration;
- Participatory project leadership;
- Digital technologies to improve design services delivery;

- Continuous attention to scope, cost and time;
- Reduced conflict among the design and building team;
- Reduced risk of litigation and liability exposure for the design team;
- Potential for designers to assume greater leadership and influence projects.

The course the authors have been evolving has been formulated to begin to address those questions. The intention of the course is to explore new practice methods, specifically IPD combined with exposure to and utilization of BIM technology as it pertains to design and decision-making in design and construction practice.

At its essence, this course is about a process and a tool: IPD is the process, and BIM is the tool. IPD is a "Relational Contracting approach that aligns project objectives with the interests of key participants. It creates an organization able to apply the principles and practices of the Lean Project Delivery System". Mathews and Howell (2005). BIM's inevitable universal adoption will influence—and be influenced by—changes in project delivery systems. Technology could become "the tail wagging the dog" in its ultimate effect on project delivery by facilitating or even forcing traditionally non-collaborative team members in the design and construction process to work more closely together.

BACKGROUND

CONTEXT

The world of architecture and architectural education is of necessity changing. The early exposure of students to the pantheon of architectural heroes helps to enshrine the concept of the architect as a rugged individualist in the minds of young students. "To Wright and Howard Roark, are added such twentieth-century greats as Le Corbusier, Kahn, Aalto, and Mies van der Rohe, along with historic figures like Palladio, Brunelleschi, and Ledoux" Cuff (1998). These hero-architects, along with a new generation of contemporary "starchitects" are known for their signature designs and uncompromising attitude that many believe are essential to achieve their prominence. Even a tempered definition of the architect: "Architects are both technologists and artists whose design talents yield buildings with beauty, stability, utility . . ." Lewis (2001) continues to perpetuate the concept of the architect as the "author" of the work, supported by a cast of characters that include consultants, builders, and owners.

This self-actualized vision of the architect as creator, coordinator, master-builder and author that has been nurtured over the years in both schools and in practice is hardly conducive to the collaborative teamwork that is essential in an integrated process of design and delivery. There is significant resistance within the profession to the sense of the architect's "loss" of control and power that the concepts inherent in IPD and Lean practices imply. It is against this backdrop that schools of architecture have begun to respond to the pressures from the profession, industry, and society.

THE SCHOOLS RESPOND

A major impetus for architecture schools to modify their curriculum occurred after the publication of what is generally known as the "Boyer Report" in 1996. This landmark publication, Building Community, A New Future for Architecture Education and Practice, was developed after extensive research of schools of architecture and the profession. The authors discovered that “architecure students and faculty are too often disconnected from other disciplines, . . . and at some schools the curriculum seems remote from the concerns of clients, communities, or the larger challenges of the human condition”. The authors further noted that “the gulf dividing architecture schools and the practice world has grown perilously wide” Boyer and Mitgang (1996).

Schools of architecture have responded to the perceived and real gap between practice and the academy by introducing new courses and placing a greater emphasis on practice concerns into their curricula: “schools *are* listening and they have reacted to the profession’s criticism over the years on a number of fronts . . . Some of the course offerings offered by the academy look to emulate the professional environment in order to gain a better understanding of the context and shifting dynamics of professional practice” Ford (2003).

The pedagogy of simulating at least a portion of the IPD process while at the same time exploring the building information model and its potential for analysis and decision-making, is the basis for a re-engineered course in computer applications and professional practice.

HISTORY OF THE COURSE

The course in question has been in the curriculum for many years. It has always been titled: Computer Applications for Professional Practice. Up until recently it had been a popular elective course that many students took in order to learn and apply advanced digital software programs that had both 3D parametric modeling capabilities, as well as 2D drafting elements. In essence, this was an advanced computer application course with a focus on Revit® Architecture, and other complimentary software titles, particularly Autodesk Ecotect Analysis®, and Autodesk Navisworks®, which provided the students with additional tools to understand the potential for environmental analysis and scheduling animations.

However, over the past few years the course has evolved in several significant ways. Most importantly, the course has incorporated “professional practice” aspects. This course now combines the tool, BIM, with a process, IPD, in a simulated case study of the first phases of the design of a simple, relatively small project. The case study incorporates the concept of teamwork involving the three critical roles in a design/construction project: the owner, the constructor, and the designer, in collaboration with an outside construction management group from the Construction Management (CM) Program.

In addition, the course has become a required course for both the Bachelor of Science in Architecture and the Master of Architecture programs. As a required course, the content is scrutinized in the accreditation process, and a recent accreditation visit singled out this course for a special commendation with particular emphasis on several elements: Collaboration, Project Management, Leadership, Financial Considerations, and a better understanding of the Client role in Architecture.

COURSE OVERVIEW

The course has a goal to prepare students to enter the profession of architecture, to prepare for licensure, and to provide for a sufficient depth of understanding of the components of architectural practice. Although integrated practices have been utilized by industry for decades, IPD is in its relative infancy in the design and construction world. The outcomes reported thus far show real promise for an industry that is itching to emerge from a half-century decline in labor productivity when almost every measurable aspect of our economy is achieving significant productivity gains. A transformative process, enabled by technology is essential to change that course.

THEORETICAL UNDERPINNINGS

We begin the course with the question: IF IT AIN'T BROKE… WHY FIX IT? To which we quickly respond: BECAUSE IT'S BROKE!, which is supported by the now famous chart from the US Department of Commerce, Bureau of Labor Statistics showing the decline in construction productivity since 1964.

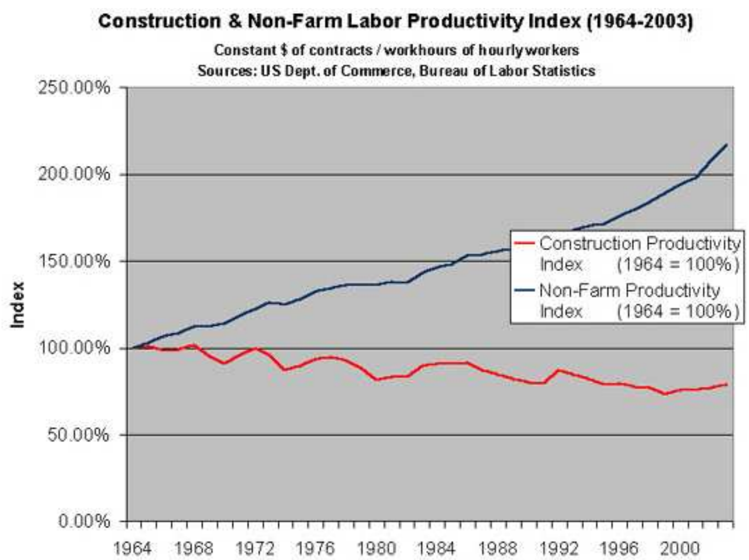

Figure 1: Construction & Non-Farm Labor Productivity index (1964-2003) Source: US Dept. of Commerce, Bureau of Labor Statistics

This example, and others makes the case for a serious exploration of alternative delivery methodologies that can help the design and construction industry catch up with the rest of the non-farm economy. Another goal is to get the students excited about the concept of integrated practice utilizing advanced digital tools to create the BIM, and at the same time overcome their resistance to collaboration and teamwork. Fortunately, there's an astounding quote from Pritzker Prize winning "starchitect", Thom Mayne of Morphosis which states: "*Prepare yourself for a profession you are not going to recognize a decade from now. Survival—if you want to survive you will change. You will not practice architecture if you are not up to speed with [BIM].*"[5] If

[5] From an address by Thom Mayne to the 2005 AIA Convention.

one of their heroes believes it, it must be true. This helps diminish the "threat" of loss of control and influence in the making of buildings, which is amplified by a new definition for a more collaborative future wherein: "Integrated practice leverages early contributions of knowledge through utilization of new technologies, allowing architects to better realize their highest potentials as designers and collaborators while expanding the value they provide." American Institute of Architects (2007).

PAST AND PRESENT PROTOTYPES OF THE INTEGRATED PROCESS

The initial assignment requires students to explore the theoretical underpinnings of integrated practice by researching both historic precedents for manufacturing in post World War II Japan such as the Kaizan process improvements and the work of William Deming, as well as more contemporary theories that have generated Lean practices and IPD. The product of the first assignment is a poster that demonstrates knowledge of the process and example(s) of contemporary projects that were developed using IPD and BIM technology.

This background assignment establishes the foundation for the rest of the course, wherein teams are formed, a project is assigned, interdisciplinary connections are made to CM "consultants", and a project is developed through the first stages of the IPD Process: Conceptualization, Criteria Design, and Detailed Design. The remaining phases of work including Implementation Documents, Agency Review, Buyout, Construction, and Closeout are anticipated and scheduled in collaboration with the construction management consultants.

ESTABLISHING THE TEAMS AND ROLES

At the outset of the course, students are divided into three or four person teams. Each student selects a role to play as designer, constructor, owner, or consultant. Each individual takes on the responsibilities of their role for the duration of the project. However, it is recognized that each team member of necessity must wear two hats, the role they are playing in the IPD team, and as a member of the BIM development team since everyone needs to learn how to develop and work with the shared model.

Students in the "owner" role meet with the proposed project's proponent, (generally a real world client), and ultimately develop the project's functional and cost parameters. Students in the "constructor" role take on responsibility for site logistics, building systems, and initial construction costs considerations, which are supplemented with the involvement of consultants from the CM program. The "designer" role is perceived by the architecture students to be the easiest to assume, yet the collaborative nature of the IPD process requires the architect to proceed with critical design decisions with the advice and consent of the owner and constructor.

ESTABLISHING GOALS AND METRICS

In order to be consistent with the IPD project approach, each team takes on risk as a team and is rewarded as a team, in this case with grades instead of bonus compensation. The teamwork starts at the earliest stage of the project when the IPD team meets to share expertise and decision-making. It soon becomes clear that the goals of the project need to be placed ahead of individual interests of the team members. It also imperative that coherent goals for a project need to be established, and as importantly those goals need to be quantified with metrics to eventually judge a project's success. Typically teams establish goals for the performance of the building: size, annual energy usage, life-cycle costs, aesthetic success, and aspects of the process: meeting the budget, schedule, and owner's functional program. The goals and metrics are the basis for the subsequent development of the project.

CONCEPTUALIZATION

The first phase in the IPD project construct is the Conceptualization phase also known as extended programming. This phase determines the scope, character, and initial costs and schedule for the project. Students are urged to "GET IT RIGHT FROM THE START". This is also the phase the determines the makeup of the team including the primary roles of owner, constructor, and designer, but also in practice to consider the appropriate engineering consultants, key sub-contractors and suppliers to expedite the goals of the project. In the author's opinion, this phase is one of the distinguishing features of an IPD/Lean project. Traditional design and delivery methodologies generally do not incorporate this critical formative stage where the most important decisions are made, the personal relationships are established, and the BIM is initiated. Some examples of elements that are developed in this phase are:

Program Development and Analysis

Working with the owner, students develop a program of requirements for the project, study the program and its implications using traditional program planning methods, explore layout options with the Affinity software program, set up room arrangement diagrams, and determine optimum physical relationships.

Site Selection and Analysis

In order to help the owner select a site, students evaluate three potential sites by: developing site selection criteria to meet the established goals, create a dynamic site selection matrix to "score" criteria for each site, rank each site on the basis of the scoring, select one of the three sites, construct the selected site as virtual model, perform a detailed site analysis for the selected site to include sun and shadow studies.

Conceptual Design

The above considerations are the basis for an analysis of conceptual layouts that involve form, orientation and positioning of three building alternatives for the selected site. A conceptual model allows each team to investigate energy related issues for each alternative by using the analytical capabilities in Revit® Architecture. The form studies and building performance results provide a rationale for the selection of a particular alternative. The selected alternative is developed in the subsequent phases of the project.

BIM ELEMENTS IN CONCEPTUALIZATION

The teams construct the site in the Revit® model, and the next steps were constructing mass model options using the Revit® mass tool or Sketch Up. The Energy Analysis tool introduced in Revit® Architecture 2012 was utilized to determine the most energy efficient form, orientation and construction method as a preliminary assumption. The students were introduced to Trelligence Affinity™ to convert the written program into a diagrammatic layout. It was used as a planning tool to test the program and room relationships. The Affinity scheme was imported into Revit and a simple room scheme was developed. The resultant conceptual design was then tested in Autodesk® Green Building Studio's energy analysis program, allowing the teams to study energy performance and life cycle implications of the form and materials under consideration.

SUBSEQUENT DEVELOPMENT OF THE PROJECT

The scheme that was defined in the Conceptualization phase was the basis for a project that was continually developed for the remainder of the semester. At each stage the building was analyzed by the IPD for conformance with their original goals and metrics. As the designs continued in development, Ecotect Analysis® was introduced to study daylight optimization and shading devices and Autodesk Navisworks® Timeliner was used to give visualization to the construction schedule that the students, headed by the CM teams, had developed in their prior meetings.

The IPD teams met with their CM counterparts throughout the semester including several half-day workshops, as well as many off-line meetings. During the early phases of work the CM consultants evaluated the building alternatives for site logistics and constructability issues, provided construction cost assessments for the alternatives, and offered constructive criticism as a member of the IPD team. This discussion resulted in the teams revisiting their initial decisions and then proceeded to develop the project into the Criteria Design, and Detailed Design phases.

INTRODUCING THE CONCEPT OF "VALUE"

The final collaborative workshop, ostensibly in the middle of the Detailed Design phase of the IPD process, the teams were given a mandate to reduce the construction cost of the project by a factor of 20 percent. This "real world" crisis initially resulted in severe consternation, but ultimately produced creative and pragmatic solutions that resulted from a truly cooperative collaboration between the architects and their CM consultants. Each team was forced to consider issues of scope, program, and quality to achieve the mandate of savings and ultimately introduced students to the value equation that is at its essence an integral aspect of Lean Construction thinking. This experience represented a true test of relationships and confidence in each other that had been built up over the course of the semester.

INTERDISCIPLINARY COLLABORATION WITH CM CONSULTANTS

The key to a successful IPD process is the quality of the collaboration and the ability to work together effectively. The addition of the CM Consultants to the IPD team proved to be among the most meaningful aspects of the entire course. Aside from the essential input on matters of constructability, costs, and schedule the CM consultants added a completely different ingredient to the mix of personalities on the teams. It's clear that no matter how well the architecture students could assume the functional roles of an IDP team, they were still architecture students. However, the CM students had a very different type of personality, more grounded and schedule driven, which provided a necessary tension between members of the team, which in effect, was more representative of a “real world” interdisciplinary team. This “clash of cultures” provided some of the teams with transformative input to their developing project,

CONCLUSIONS

It is evident that Architecture and CM programs are seeking ways to integrate BIM and IPD topics and technologies into the curriculum. Alongside this, there is an increasing understanding that these technologies and systems used today in construction encompass all disciplines and are used to describe and document the contributions of each member of a project team Fisher & Kunz (2004). Consequently, the collaboration among the Architecture and CM students, helped both programs address IPD and BIM theories, technologies, and their interdisciplinary nature. This successful collaboration is resulting in new courses and greater coordination between these design and construction disciplines.

The authors recognized the need to teach IPD and Lean practices in Schools of Architecture. By integrating the architecture students with CM students we have been able to simulate IPD and a Lean Construction environment: an environment where technical skills and communication are a necessity; an environment where mutual respect and collaboration are required: an environment where our students will be playing a leadership role in a few short years.

REFERENCES

AIA (2008). *On Compensation, Considerations for Teams in a Changing Industry,* American Institute of Architects (AIA), Integrated Practice Discussion Group.

AIA (2008) *AIA Document E202TM – 2008*. Building Information Modeling Protocol Exhibit. American Institute of Architects (AIA)

AIA (2007) *Integrated Project Delivery: A Guide*. American Institute of Architects, (AIA), National AIA California Council, version 1.

AIA (2010). *Contract Relationship Diagrams.* American Institute of Architects, AIA Contract Documents**,** June 2010

Ballard, G. (2000). “Managing Work Flow on Design Projects.” Presented at the *CIB W96 Architectural Management Conference,* Atlanta, Lean Construction Institute, 19-20 May 2000

Bernstein, P.G. (2010). “A Way Forward, Integrated Project Delivery.” *Harvard Design Magazine,* 32, Spring/Summer.

Boyer, Ernest, Mitgang, Lee, (1996). *Building Community: A New Future for Architecture, Education, and Practice,* The Carnegie Foundation for the Advancement of Teaching, Princeton, NJ, 172 pp.

Cuff, Dana, (1991). *Architecture: The Story of Practice,* MIT Press, Cambridge, MA, 320 pp.

Elvin, George, (2007). *Integrated Practice in Architecture, Mastering Design-Build, Fast-Track, and Building Information Modeling,* John Wiley & Sons, Hoboken, NJ, 272 pp. 272.

Fisher, M., & Kunz, J. (2004). *The Scope and Role of Information Technology in Construction.* Center for Integrated Facility Engineering #156, Stanford, CA.

Ford, Chris, (2003). “The Gap and Its Effect on Architectural Education”, Accepted for publication in the *Proceedings of the ACSA-SE Regional Meeting: Finishing School Conference*, Atlanta, GA, 6-9 November, 2003.

Howell, Greg, and Lichtig, Will (2008). “Lean Construction Opportunities Ideas Practices”, Presented to the *Introduction To Lean Design* Workshop, Cascadia LCI, Lean Construction Institute, 15 September.

Lichtig, William A. (2006). “The Integrated Agreement for Lean Project Delivery” *Construction Lawyer*, American Bar Association, 26 (3), Summer, 2006.

Love, A.T., (1993). “Survey of the Scheduling Course Topics offered by ASC Member Schools”, Presented at the *29th Annual ASC Conference*, Fort Collins, CO., 1-6.

Matthews, Owen, and Howell, Gregory A., (2005). “Integrated Project Delivery an Example of Relational Contracting”, *Lean Construction Journal*, 2 (1), April 2005, 46-61.

Krygiel, Eddy, Bradley, Nies, (2008). *Green BIM, Successful Sustainable Design with Building Information Modeling*, Indianapolis IN, Wiley Publishing Inc.

Woo, J. (2007). “BIM (Building Information Modeling) and Pedagogical Challenges”, Accepted for publication in the *Proceedings of the 43rd International Associated Schools of Construction Conference*. Flagstaff, AZ, 12-14 April, 2007.

Yudelson, Jerry, (2008). *Green Building Through Integrated Design*, McGraw-Hill Companies, Inc., New York, 261 pp.