

Course or Class Topic: Evaluating the Implementation of Lean Construction into a University Curriculum

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Efficiency in the construction industry, or the lack thereof, has been a topic of research for decades. The construction industry is the only major U.S. industry segment that has failed to realize quantifiable increases in overall productivity. Attempts to address this problem have focused on project delivery systems such as Design-Build, CM, and, most recently, IPD (Integrated Project Delivery). In recent years (primarily the last 10), with the introduction of LEED and Lean Construction, research has focused on planning and management in an attempt to increase efficiency factors of the built environment process. To date, most research in the realm of Lean Construction has focused on methodology of the process and practitioner implementation. This paper serves as a foundation for considering the introduction of Lean Construction into university curricula, addressing aspects of format and curricular structure. An in-depth literature review was used as the primary source for developing the argument on the validity of Lean Construction within university curricula—ultimately recognizing its pertinence as a topic of instruction. Results of the research indicate relevance for integrating Lean Construction into university curricula and identify little precedence concerning format and delivery method.

Key Words: Lean Construction, CPM, project planning, silos, studios, efficiency

Introduction

Improving efficiency is an essential part of maintaining or increasing profitability for many, if not most, industries, including construction. Logistical considerations of labor, equipment, and material are of paramount concern. Most industry segments in the United States have seen quantifiable increases in overall productivity. However, the construction industry is the only major segment that has failed to do so. Data from the U.S. Department of Labor indicate the construction industry has a half-century history of little, if any, growth in overall productivity (see figure 1)—much of which is attributable to poor project planning and management.

The industry standard for construction planning and management is the critical path method (CPM), a methodology focused on identifying the logical order of material placement, which correspondingly affects the project's overall assembly timeline. By virtue, CPM is the method most widely accepted and studied in higher education construction programs. While CPM is relevant to construction practice, its focus on the building assembly often overlooks logistical aspects associated with pre-assembly. As a result, significant overlap and duplication occur in the processes used by various trades for placement of work. Studies monitoring movement on construction sites identify scenarios where materials and equipment are moved multiple times before reaching their permanent placements (Alves, 2000). These aspects of planning and management are addressed in Lean Construction methodology.

University educators are tasked with providing students the necessary tools to become leaders within their chosen professions. This means equipping them with the knowledge of both industry standard practices and innovations within the discipline. As the industry standard, CPM also is the primary focus when teaching construction scheduling. In recent years, Lean Construction has made inroads in industry and has become a topic of conversation in higher education construction programs.

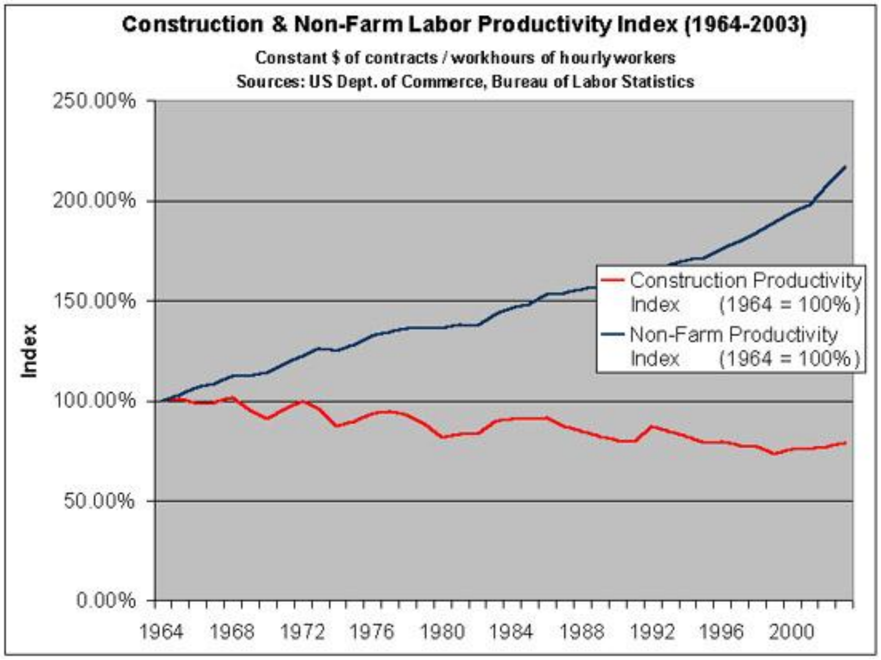

Figure 1

The Lean delivery system has begun to gain traction over the last decade as case studies highlighting implementation strategies have been developed (Naney, et al, 2012). While these studies address both advantages of its implementation and barriers to adoption, the overwhelming message indicates the adoption of Lean strategies as a growth segment within the construction industry (Demir, et al, 2012). Students preparing to become industry leaders must learn the aspects of a system taking hold in leading construction firms. However, execution of such notions may be easier said than done.

Introduction of a new study area within a curriculum raises questions of appropriate content and delivery format. Does the topic in question bear the depth and breadth necessary to warrant the development of an entire course, or is it simply a topic within a greater context of study? Additionally, what is the delivery format of the material and does that have an effect on determining the appropriate course of action in its application? These were aspects of concern raised by professors in the Building Construction Science program at Mississippi State University when examining the best method to integrate Lean Construction concepts into MSU's curriculum.

This paper presents an in-depth literature review to inform readers about Lean, addressing its background, development, industry perception, and implementation in an effort to better understand the role of Lean in the AEC industry. This information is intended to support the appropriateness of including Lean Construction in a higher education construction curriculum. The literature review suggests that Lean is not just a "fad" but that it will continue to grow in popularity among AEC practitioners, which ultimately supports the argument that it should be an element of instruction. This introduces the discussion of topical content in relation to curriculum format and its impact on the appropriate delivery outcome. If Lean is going to be incorporated into university curricula, should it be placed into its own course or as an element of an existing course?

Literature Review

Productivity & CPM

The construction industry's productivity has been declining since the mid-1960s at a compound rate of .48 percent per year (Teicholz, 2001). Teicholz further points out in contrast that all non-farm industries over the same time period show an increase in labor productivity of 1.71 percent per year. Management ineffectiveness has been widely cited as the principal factor affecting productivity. A study published in 1983 by the Business Roundtable identified that poor management practices account for more than 50 percent of wasted time on construction projects (BRT, 1983). Project planning and scheduling is a key contribution affecting on-site craft worker productivity (Olson, 1982). Recent data collected from a survey of the craft-worker community, trades which comprise approximately 54 percent of the construction workforce (Bureau of Labor Statistics, 2011), indicate material availability and sequencing of work assignments as top factors affecting job-site productivity (Dai, et al, 2009). One craft worker account in the study by Dai highlights this notion:

> In general, there's a lack of planning. It seems there is a lack of coordination amongst the management ranks. As a craft worker, that's all we really can do is plan our day. And the people above us have to plan the rest of the work. Getting material, keeping the tools out here, keeping what we need out ahead of us. Planning leads to productivity.

The critical path method (CPM) has traditionally been the technique of choice for planning and scheduling construction projects (Mendes & Heineck, 1998). Because CPM is so widely accepted in academia, it is listed as required topical content by the American Council for Construction Education in its *Document 103* (ACCE, 2012). CPM is a linear organizational strategy focusing on identifying the logical order of material placement, affecting a project's overall assembly timeline. However, effective project planning involves more than just putting activities in order, as CPM indicates (Bertelsen, 2003).

Some research indicates critical path-based planning techniques are not adequate for eliminating waste within construction projects (Elzarka, 2006). Because CPM incorporates activities that are of a non-critical influence, this would indicate a factor of waste has been built into the project schedule (Melles & Welling, 1996). This contention supports the previous data identifying stagnant productivity trends associated with current methods of planning and scheduling. With the concept of establishing "critical" elements to the project execution inherent in critical path planning, resource capacity and material requirements are abstract at best within development of the schedule (Mendes & Heineck, 1998). Mendes and Heineck further explain that CPM plans are commonly poor when predicting the future of the project because of the lack of information about actual deliveries and durations.

Lean Construction

Lean Construction is a method developed from the concept of lean production put forth through the Toyota Manufacturing System, focusing on maximizing effectiveness of production while also maximizing efficiency of the process (Faniran, 1997; Pheng & Fang, 2005). In essence, the key to lean is having only the necessary material on hand for production in a given work cycle. While this seems common sense on the surface, the idea is contradictory to the traditional assembly line approach implemented by Henry Ford, where maximizing production meant running the line at full capacity focusing on cost optimization (Elzarka, 2006). Elzarka explains this one-dimensional approach created defects where the multi-dimensional lean production system addresses customer satisfaction, waste minimization, and quality, among others. Lean Construction draws on this philosophy.

The Lean Construction system utilizes the lean manufacturing philosophy as a framework for developing a more effective management planning process, which means clearly defining objectives of the delivery process to maximize performance for the customer at the project level (Howell, 1999). The challenge is manipulating the lean manufacturing strategy to fit the unique characteristics of construction. Some of these characteristics are identified as large projects, immobility of the built product, and changing material types (Gann, 1996).

Some could question whether lean is as appropriate for the construction industry, which performs its work on ever-changing and perennially dirty job sites, as it is for other manufacturers, who have the advantage of permanent, conditioned factories (Gann, 1996). Some might even describe Lean Construction as a "fad" or buzz word. This perspective alone could call into question the value of teaching it period, let alone discussing its pertinence as a course or class topic. Established research has identified a multitude of factors (see Table 1), as potential barriers to the use of lean in a construction context (Demir, et al, 2012; Gann, 1996; Ankrah, et al, 2005; Andersson, et al, 2006). Given this perspective, Demir proposes the AEC industry has two options when considering the adoption of Lean: change the project's complexity or change how the process is managed. The authors propose these are actually the same and, by extension, suggest industry is actively pursuing both aspects of this paradigm. Widely published research on the adoption of technologies, such as BIM and collaborative project delivery approaches—

including design-build and IPD—supports this position (Gerber & Kent, 2010). In this context, industry participants can no longer wonder if Lean is good; rather, they must consider what will happen if they do not adopt it (Naney, et al, 2012). Practitioners in the built environment are moving toward adoption of more innovative approaches aimed at improving the goods and services they provide. This includes acquiring individuals with the knowledge and understanding of these cutting-edge concepts, confirming Lean is a strategy deserving of a seat in higher education curricula.

Table 1
Potential barriers to Lean Construction

o Industry fragmentation o Negative relationships between parties (architects, contractors, sub-contractors) o Number of parties involved in construction projects o Changing project teams	o Changing project conditions o Lack of client support o Disparity between design and execution o Perspective of Lean being process focused and not people focused

Lean in the Curriculum

Considering the notion that Lean Construction should be included in a curriculum, the next question is where in the curriculum it should be placed—a traditional lecture course, an inquiry-based studio course, or a specialty summer course. This problem can be reframed as “silo, studio, or summer.”

For traditional programs, the logical—and perhaps only—option is the three-hour lecture or “silo” course. For programs based on silo courses, two options exist: creating a new course or incorporating Lean Construction into an existing course.

Silos

Since Lean focuses on management in the realm of planning and scheduling, placing its content into an archetype course such as a project controls would make sense, at least initially. However, such an approach poses at least three potential problems.

1. Placing new content into a mature, established course requires the displacement of established content. All existing courses have a certain amount of inertia, for reasons good and bad. How would Lean fit into an established scheduling course? What would be displaced: basic scheduling concepts, Gantt charts, CPM, or specialty scheduling? This is not an insurmountable issue, but it is a potential concern.

2. A more important issue is the idea that a traditional lecture course may not be the best platform for engaging with a complex process such as Lean Construction. Lectures, quizzes, and exams can address aspects of Lean, but only superficially. To understand how Lean concepts affect a project, students would be better served by inquiry-based or problem-based learning. For example, “The first goal of Lean Construction must be to fully understand the underlying ‘physics’ of production” (Howell, 1999). Such a complex concept as the “physics of construction” could be addressed superficially in a quiz or in slightly more depth in an exam essay question. However, understanding “the physics of production” begs for an iterative series of projects in which students compare standard and Lean projects. Most lecture courses cannot absorb such an intensive series of projects.

3. The nature of a silo course makes it difficult to integrate a subject area, in this case Lean Construction, with related activities. While Lean is primarily concerned with schedule management, it also affects and/or is affected by cost estimating, procurement, work site layout, and numerous other issues. A three-hour lecture

> course on Lean suggests that it is a distinct activity isolated from other construction activities, which of course it is not.

Studio

To address the limitations of traditional lecture courses, construction programs at California Polytechnic Institute at San Luis Obispo and Mississippi State University have created a series of inquiry-based courses, called “labs” or “studios” respectively (Monson & Hauck…A Comparison, 2012). At both programs, traditional courses in construction fundamentals, such as cost estimating, scheduling, and job site safety, have been eliminated, and the respective material transferred into the lab or studio courses. These courses, worth five to six credit hours each, accommodate significant contact hours, complex projects, and iterative work. Importantly, these courses also accommodate the integration of different problem types. For example, a scheduling problem can become a job site safety problem which in turn has an impact on a cost estimating. Such multivariate problems are particularly appropriate for future construction professionals:

> Just as constructors in practice are called on to deal with methods, contracts, estimating, scheduling, personnel, and subcontractor issues simultaneously and creatively, construction students need to learn all of these in an integrated rather than sequential fashion (Monson & Hauck…A Model, 2012).

Some construction programs are making the transition to labs or studios, even for relatively narrow curricular content. Designing a course to address specialty contracting (specifically MEP contracting), faculty at Cal Poly chose the lab format. Scheduled under the quarter system, the experimental class was worth eight credits and required a total of 19 contact hours a week (Korman, et al, 2008). Although introductory lectures were part of the lab, the bulk of class time was spent on various projects, many of which required teamwork.

Summer Option

If a program does not utilize labs or studios and does not want to shoehorn Lean Construction into a lecture course, a third option exists—presenting the material in an optional summer class. This approach has potential advantages and disadvantages.

The primary advantage of creating an optional summer class for Lean is the avoidance of conflicts with other components of the curriculum. The existing scheduling course or courses could remain as structured.

The disadvantages of an optional summer class are threefold.

1. An optional class is just that—optional. One could argue, based on the growing interest in LEED projects, Integrated Project Delivery (IPD), and Building Information Modeling (BIM)—and Lean Construction’s relation to all three, that Lean should be taught as an essential part of any construction curriculum. This message is not conveyed by placing it in an optional summer course.

2. A stand-alone Lean Construction course implies that Lean is an isolated process. As previously discussed, this is not the case.

3. Summer routines at many universities are not predictable. At Mississippi State University, for example, both “Maymester” and summer courses are offered university-wide. However, the Building Construction Science Department (BCS), which was formed in 2007, has no experience with summer courses to date. Moreover, many BCS students choose to work during the summer, for experience and/or financial reasons. Thus, the pool of available students is relatively small, and whether any summer BCS course makes or not would remain constantly in flux.

Topical Content

The depth and breadth of content necessary to cover Lean Construction will ultimately determine Lean's placement within a curriculum. To date, literature discussing the teaching of Lean Construction methods is minimal. The causes of this are likely twofold (Rybkowski, et al, 2012):

1. Most educational strategies are focused at the industry level where workshops are conducted by industry stakeholders in an effort to improve their project delivery outcomes.

2. Practitioners and academics have expressed concern that Lean concepts are difficult to grasp.

Organizations such as the International Group for Lean Construction, the Lean Construction Institute, and the Associated General Contractors offer training seminars, which are mainly focused on practitioners (Rybkowski, et al, 2012). Most of these seminars are two to three days in length and concentrate on the history, principles and techniques, and case studies dealing with Lean Construction (Tsao, et al, 2012). Their structure would indicate an elevated awareness by the participants of current construction strategies—knowledge most undergraduate students would lack.

In academia, Michigan State University, Texas A&M, and North Carolina State University offer courses in Lean. Although the course content structure was not accessible for the purposes of this research, information available identifies these courses as full semester, stand-alone classes (Rybkowski, et al, 2012). Other programs identified by Tsao, et al. were also independent courses ranging from eight weeks to 16 weeks, depending whether the institution operates on quarters or semesters respectively. Of the four programs highlighted, three are graduate level programs. Regardless of the setup—separate course, integrated content, graduate or undergraduate—the proposed core content seems to share some commonalities (see Figure 2).

TEACHING STRATEGIES TO ACHIEVE LEARNING OUTCOMES	
Published Case Studies Reading Assignments	Comprehensive collections of LC readings in "Readings" section of LCI's webpage, iglc.net, and leanconstructionjournal.org provide peer-reviewed case studies free of charge.
Simulations	Effective way to demonstrate in a controlled environment how the concepts are inter-related. Provide framework for anchoring discussions during the semester. Facilitate comprehension of concepts by students without AEC experience and helps practitioners relate the variables to their own environments.
Team Projects	Help students conduct a deeper-dive into lean concepts and techniques. Challenge students to engage in critical thinking.
Discussion Facilitations	Develop facilitation skills in students. Increase student ownership of course. Explore cause and effect relationships in AEC practice.
Guest Speakers Field Trips	Expose students to how course concepts are adapted and applied in real project environments. Provide proof of concept to the theory as students see its implementation by different professionals.
Value Stream Mapping (swim-lane / process maps)	Make the analysis of systems more visual. Increase transparency of workflow and handoffs of work between AEC practitioners.

Figure 2: Teaching Strategies to Achieve Learning Outcomes
Source: Tsao, et al. 2012

The depth and breadth associated with understanding Lean Construction justifies the need of offering it as an independent course. Although extensive literature addressing the teaching of Lean Construction is not available, the information that is available indicates growing support of its adoption in higher education. In 2001, the Lean Construction Institute launched the LCI Academic Forum, focused on research and teaching initiatives in Lean Construction (Tsao, et al, 2012). Similar to the LCI Academic Forum model, the International Group for Lean

Construction marked a milestone in 2012 by adding a "Learning" area of concentration in their annual conference proceedings (IGLC Website, 2012).

Conclusion

Our literature review suggests the need for higher education institutions to incorporate Lean Construction methodologies into their curricula. At the onset of this research, the authors posed the question whether Lean should be incorporated as a stand-alone course or a topic within an existing course. The results of the research have given rise to a third paradigm of consideration—is Lean really more of a culture rather than a singular topic of focus? This raises an additional area of research consideration. If Lean is approached as a culture rather than a singular area of focus, is the appropriate form of student exposure a broad spectrum over many courses throughout an entire curriculum?

Given the complex nature of Lean Construction, implementation strategies should not be taken lightly. An extensive commitment on the part of the instructor—and possibly an entire program—is needed to develop the appropriate knowledgebase for proper instruction of the necessary content. Additionally, programs examining whether to add Lean Construction to their curricula may be constricted based on their structure of silo, studio, or summer. A precedent has yet to be established for the appropriate form of inclusion, which offers opportunity for continued research. The results of the research anecdotally identify the need for Lean Construction exposure in higher education curriculum and foster support of the argument for further quantitative studies into appropriate delivery format and topical content.

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