

Lean Construction – A Promising Future for MSU

White Paper

Construction Management as a field of applied science has escaped canonical definition. But one typical definition is that of Clough and Sears (1994) wherein Construction Management was defined as “The judicious allocation of resources to complete a project at budget, on time, and at desired quality”. This definition captures the essence of what inspired, drove, and guided practice and research in the Construction Management field. However, the failure and inability of the conceptual models of Construction Management (time-cost-quality tradeoff, work breakdown structure, critical path methods, and earned value) to deliver on the mantra of ‘on-time, at budget, and at desired quality’ is evident to practitioners and academics alike. For example, recurring negative experiences on projects, as manifested by endemic quality problems, lack of timely communication and coordination amongst project stakeholders, and rising litigation, indicate that construction projects are low efficiency systems (Koskela 2000 and Lepatner 2007). Analysis of project schedule failures by Ballard and Howell (2003) and CMAA (2006) also indicated that “normally only about 50% of the tasks on weekly work plans are completed by the end of the plan week” and that most of these planning failures were possible to mitigate by contractors through an “active management of variability, starting with the structuring of the project - as a temporary production system - and continuing through its operation and improvement.”.

Koskela's seminal 1992 report argued that Construction Management is a transformation-based philosophy where the main focus is on transforming inputs to outputs with typically no management of the transformation process itself. He further stated that the mismatch between the conceptual models of construction management and observed reality on projects underscored the lack of robustness in the existing constructs of Construction Management and signaled the need for a comprehensive theory of production management in construction.

Koskela conceived a more overarching production management paradigm for project-based production systems. Koskela presented the ‘TFV’ theory of production wherein production was conceptualized in

three complementary ways, namely, as a Transformation (T) of raw materials into standing structures, as a Flow (F) of the raw material and information through various production processes, and as Value (V) generation and creation for owners through the elimination of value loss (realized outcome versus best possible).

Since 1992, practitioners and researchers have been working towards the formation of a new paradigm to design and build capital facilities. This approach is known as Lean Construction, wherein construction is viewed as a project-based production system.

The paper discusses the founding principles of Lean Construction. This is a vast topic of discussion and needs more space than allotted here. Hence, the paper is limited to the discussion to key concepts and benefits of Lean Construction, supported by examples from the construction industry both from the owner and the subcontractor perspective. The paper ends with suggestions for MSU for implementing tools and techniques to start its lean journey.

Introduction

Thus far, in this discussion, no explicit definition of Lean Construction has been stated. Prior to doing that, we must talk about Lean Production. Following is a wonderful and authentic excerpt describing what Lean Production is. This description also captures the essence of Lean Construction. The excerpt is from a June 16, 2004 posting by Mr. Norman Bodek to the NW LEAN group (<http://www.NWLEAN.net/>). Mr. Bodek is considered the godfather of the lean movement outside of Japan. He translated and published the writings of Taiichi Ohno, Shigeo Shingo, Seiichi Nakajima, and others who were the architects behind the Toyota Production System.

“.....Lean is fundamentally empowering all workers to be partners in your continuous improvement efforts. You ask them to make their work easier and more interesting. You challenge them to grow every day on the job. You ask them to cut costs, to improve safety, to improve quality and reduce the time line to deliver superior products and services to their customers.

And you listen, listen, listen and learn from them. Of course, we focus on the wastes but we allow everyone to participate.....There are two barriers to advancing lean manufacturing; one is just living in the old paradigm where we don't ask workers to be involved in creative problem solving. "Keep your brains at home," was the subliminal sign over the factory's front door." And secondly is the incredible resistance to change, the "not invented here syndrome." Yes, you can "always," find reasons not to do something. Most people are experts in this. There are those that like to play the "devil's advocate," and end up doing nothing....Ohno and Shingo both loved to say simply - "Do it!" And then leave you the challenge to figure it out for yourself. They rarely ever had a cookbook approach for you. In fact, Ohno would never let anything be written down on how to do lean. He wanted it to be a system that allowed for constant change. Sure, their disciples created the Kaizen Blitz, which became a million dollar product for them. While others have created Six Sigma another million dollar product. Somehow we just resist change until everyone is doing it then we jump on the bandwagon".

So, what is Lean Construction? A simple, not simplistic, definition is that Lean Construction is a "way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value (Koskela et al. 2002)".

Another definition states that Lean Construction is: A holistic facility design and delivery philosophy with an overarching aim of maximizing value to all stakeholders through systematic, synergistic, and continuous improvements in the contractual arrangements, the product design, the construction process design and methods selection, the supply chain, and the workflow reliability of site operations (Abdelhamid 2004).

It is critical to note that while Lean Construction is identical to Lean Production in spirit, it is different in how it was conceived as well how it is practiced. Implementing Lean Construction has its benefits reaped by not only contractors, a popular misconception, but the architect and owner as well who are set to gain a lot by this practice. Sutter Health, a California healthcare provider, has requested that its contractors use a lean construction

approach in their 2004-2012 \$6 billion dollar construction program. Sutter Health states that their first Lean Construction project alone saved \$100,000 from the planned budget and 60 days of scheduled time (ENR 2007).

Contractors like Turner and DPR Construction, who are working with Sutter Health, others like Walbridge Aldinger, Boldt Construction, and Messer Construction have also reported benefits of implementing Lean Construction. MSU can reap the double benefits of lean construction as a client and on its own self-performed works, by saving on time and money and improved quality of projects, building relationships with the service providers, and providing value to the end users who otherwise are often not involved in the entire process.

The concept of 'Lean' is attributed to the manufacturing industry, in particular, Toyota Motor Company with its unique Toyota Production System (TPS) for manufacturing cars. The introduction of the concept to construction began when the traditional theories of production were questioned by researchers and Koskela proposed the new integrated view of Transformation, Flow, and Value (TFV) theory of production.

The conventional theories of production are based on separate lenses of transformation view, flow view and value view which as their name suggests look at a) production as transformation of raw material into finished product (Transformation view) which means it focuses on making individual tasks efficient, b) production as flow of material from its raw state to finished product going through the stages of inspection, moving, waiting, transformation (Flow view) thus focuses on minimizing the waste (non-value adding activities), and c) production as a form of value generation where the focus is solely on whether the customer demands have been met as per his/her requirements. Table 1 captures this discussion.

Fundamentals of Lean Production

Elements of Lean Production have been inspired by the work of Henry Ford's introduction of the assembly line production system. Toyota refined and created many elements to arrive at what is today called Lean Production. This system of production has been well

	<i>Transformation view</i>	<i>Flow view</i>	<i>Value generation view</i>
<i>Conceptualization of production</i>	As a transformation of inputs into outputs	As a flow of material, composed of transformation, inspection, moving and waiting	As a process where value for the customer is created through fulfillment of his requirements
<i>Main principle</i>	Getting production realized efficiently	Elimination of waste (non-value-adding activities)	Elimination of value loss (achieved value in relation to best possible value)
<i>Methods and practices</i>	Work breakdown structure, MRP, Organizational Responsibility Chart	Continuous flow, pull production control, continuous improvement	Methods for requirement capture, Quality Function Deployment
<i>Practical contribution</i>	Taking care of what has to be done	Taking care of that what is unnecessary is done as little as possible	Taking care of that customer requirements are met in the best possible manner
<i>Suggested name for practical application of the view</i>	Task management	Flow management	Value management

Table 1. The TFV Theory of Production (Koskela 2000).

researched and appears to be governed by the following 14 principles (Liker 2004):

1. Base your management decisions on a long term philosophy, even at the expense of short term financial goals.
2. Create continuous process flow to bring problems to the surface.
3. Use "pull" systems to avoid overproduction.
4. Level out the workload.
5. Build a culture of stopping to fix problems, to get quality right the first time.
6. Standardized tasks are the foundation for continuous improvement and employee empowerment.
7. Use visual control so no problems are hidden.
8. Use only reliable, thoroughly tested technology that serves your people and processes.
9. Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others.
10. Develop exceptional people and teams who follow your company's philosophy.
11. Respect your extended network of partners and suppliers by challenging them and helping them improve.
12. Go and see for yourself to thoroughly understand the situation.
13. Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly.

14. Become a learning organization through relentless reflection and continuous improvement.

It is important to understand that lean is not a technology that comes in a box and can be purchased and used at a site. Instead it's a culture that has to be imbibed within the organization and practices by its workers in order to successfully implement lean. As Womack and Jones (2003) mention in their book *lean thinking*, to be a lean manufacturer requires a way of thinking that focuses on making the product flow through value-adding processes without interruption (one-piece flow), a "pull" system that cascades back from customer demand by replenishing only what the next operation takes away at short intervals, and a culture in which everyone is striving continuously to improve.

Lean + Construction = Lean Construction

When the concept of lean was adapted from the manufacturing industry, the concern was in abstracting the first principles that were underlying Lean Production and then tailor them to the Construction Industry. The challenge was then how to take the Lean Construction principles and make them operational. A new project delivery system was needed that encompasses all the core principles of Lean Construction. This was however, not intended to be a formulaic delivery system as Lean Construction does not come with a standard set of tools.

A lean project delivery system is one that is structured, controlled, and improved in pursuit of

maximizing value to owners and workflow reliability on construction sites.

The Lean Project Delivery System (LPDS) is a conceptual framework developed by Ballard (2000) to guide the implementation of lean construction on project-based production systems, i.e., the structures we build. The reader is referred to (Ballard, 2000) for a detailed account of the LPDS model. The LPDS was developed as a set of interdependent functions (the systems level), rules for decision making, procedures for execution of functions, and as implementation aids and tools, including software when appropriate.

- **Lean Design** consists of Conceptual Design, Process Design, and Product Design.
- **Lean Supply** consists of Product Design, Detailed Engineering, and Fabrication/Logistics.
- **Lean Assembly** consists of Fabrication/Logistics, Site Installation, and Testing/Turnover.
- **Production Control** consists of Work Flow Control and Production Unit Control.
- **Work Structuring and Post-Occupancy Evaluation** are thus far only single modules.

Essential features of LPDS include:

- The project is structured and managed as a value generating process
- Downstream stakeholders are involved in front end planning and design through cross functional teams

Figure 1 illustrates the LPDS as originally depicted in Ballard (2000). As reflected in Figure 1, LPDS is shown as a series of overlapping triads, and within each triad different processes are to be completed. The triads and the processes contained within them are as follows:

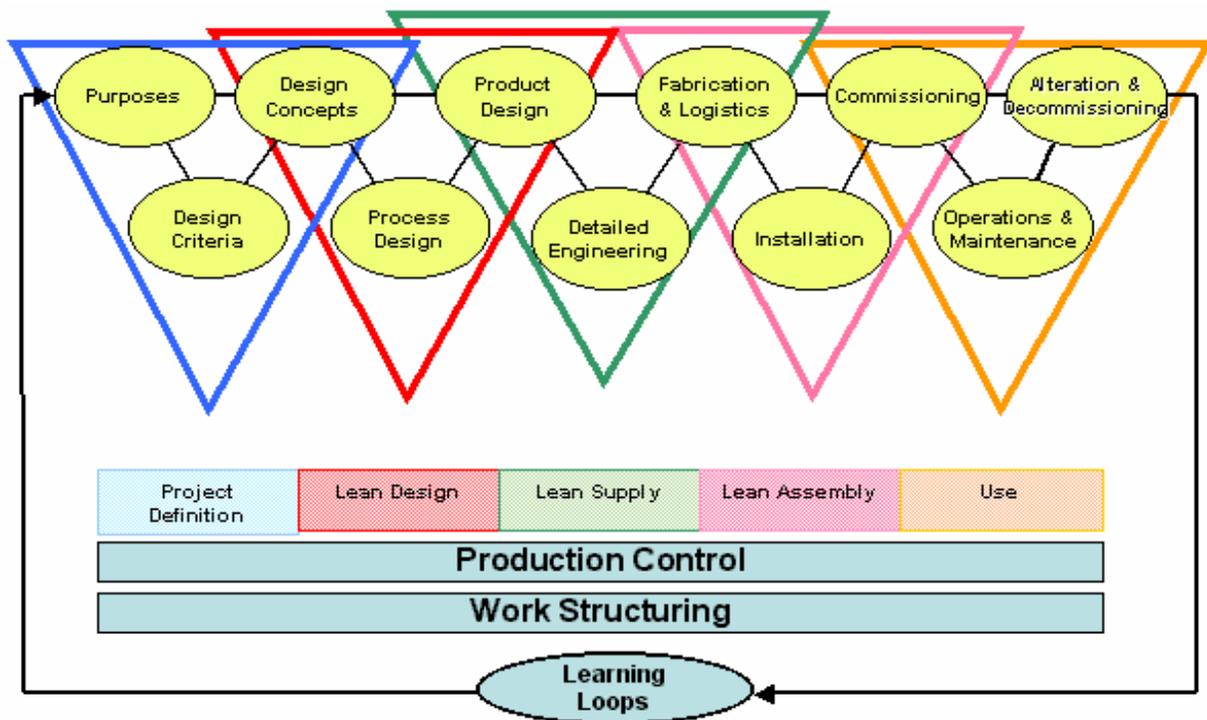


Figure 1. Lean Project Delivery System (Ballard 2000)

- The **Project Definition** phase consists of the modules: Needs and Values Determination, Design Criteria, and Conceptual Design.
- Project control has the job of execution as opposed to reliance on after-the-fact variance detection
- Optimization efforts are focused on making work flow reliable as opposed to improving productivity

- Pull techniques are used to govern the flow of materials and information through networks of cooperating specialists
- Capacity and inventory buffers are used to absorb variability
- Feedback loops are incorporated at every level, dedicated to rapid system adjustment; i.e., learning.

As depicted in the LPDS graph each phase of the project overlaps with the adjacent phases indicating the need to incorporate interests of the subsequent phases. This is the major departure of the LPDS from the traditional project delivery systems, where construction details are thought of only after the project has been bid.

The different phases of LPDS provide different areas of improvement within a project delivery system. Although all the phases are crucial for success of a lean project, the heart of the LPDS lies in Work structuring and Production Control (Abdelhamid 2008).

Work Structuring (Ballard 2000)

"Work Structuring" is a term created by LCI to indicate the development of operation and process design in alignment with product design, the structure of supply chains, the allocation of resources, and possible off-site fabrication opportunities. The purpose of work structuring is to make site operations flow in a reliable and quick manner while delivering value to the customer.

Work structuring is the most fundamental level of process design, answering the following questions (Ballard 2000):

- In what chunks will work be assigned to specialist production units (PUs)?
- How will work chunks be sequenced through various PUs?
- In what chunks will work be released from one PU to the next?
- Where will decoupling buffers be needed and how should they be sized?
- When will the different chunks of work be done?

In essence, works structuring is thinking production process during product design. LWS can be accomplished using a myriad of tools such as BIM, Target Costing, set-based design, CPM, simulation, etc. This level can be easily achieved by a design/build arrangement where the architect and the contractor work toward meeting the spirit of LWS, which is to think production during design.

Production Control

Production control governs execution of plans and extends throughout a project. "Control" first of all means causing a desired future rather than identifying variances between plan and actual. Production control consists of work flow control and production unit control. Work flow control is accomplished primarily through the lookahead process. Production unit control is accomplished primarily through weekly work planning. (LCI Website). The Last Planner system (Figure 2), is central to the process of production planning and control.

During the front end planning process, a master schedule is developed and serves to demonstrate the feasibility of project completion by the target end date. A higher level of level of detail at this point is inappropriate because of uncertainty regarding the future. Master schedules are expressed at the level of milestones, typically by phase. Phase schedules are produced by cross functional teams using pull techniques closer in time to the scheduled start of the particular phase. Phase schedules feed into lookahead windows, usually 3 to 12 weeks in duration. The Lookahead process is a screening processes wherein scheduled tasks are made ready for assignment by ensuring that no constraints exist that would prevent the task from resuming. These ready and constraint-free tasks are placed in a Workable Backlog. The lookahead process generates early warning of problems so there is more time to resolve them.

Weekly work plans are weekly production assignments, established based on the ability to perform them and not only based on what "should" be done. To measure the effectiveness of the production system to carryout assignments (commitments), the number of completed assignments is expressed as a ratio of the total number of assignments committed in

Lean in Practice

As with any new paradigm, widespread use is gradual

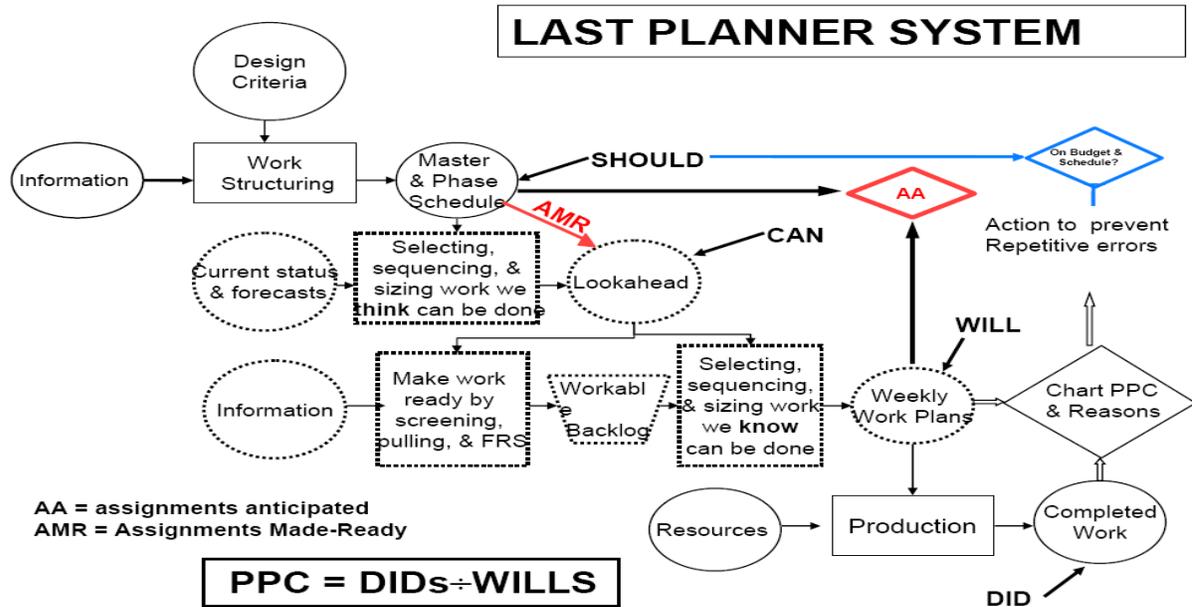


Figure 2. Last Planner System (LCI Website 2008)

PPC can take on values from 0 to 100%, with the latter being the best case. A high PPC reflects a well-planned production process with high workflow reliability between production units. A PPC less than 100% reflects a failure in the production planning process. Understanding the reasons for the failure will enable future improvement of the planning process formed by selection of tasks from Workable Backlog.

As indicated in Figure 3, a hypothetical conical structure that has three distinct levels used to represent Production Control, Lean Work Structuring, and Relational Contracting (Abdelhamid 2008). To get the highest level of reliable workflow on a construction site, which leads to cost and time savings, then all levels of the LPDS cone need to be used. If the first level is used, i.e., Production Control, then reliable workflow will be achieved but not as high or consistently as when the second level and third level are implemented.

and evolves over time. Adoption of Lean Construction is gaining momentum and companies are now requesting candidates with Lean Construction backgrounds and universities are offering course work on the topic. Examples are provided of some recent applications.

Sutter Health (Owner)

As mentioned earlier in the paper, Sutter Health, a health care provider company on the west coast, initiated the use of lean construction techniques in 2004 on all of its projects by introducing lean project delivery. Sutter uses a new contractual agreement called the Integrated Form of Agreement (IFOA), which embodies concepts found in a 'relational contract' rather than in the typical 'transactional contract'. The IFOA is signed by all 3 parties namely owner, architect, and contractor. Rather than focusing on risk transfer, the agreement creates an Integrated Project Delivery Team that is responsible for the project management, and that deploys a policy of "share the gain and share the pain". The contract calls for a consensus based approach on making decisions. The core group, formed by members from all participating parties, adopts a Target Value Design approach, not a value engineering scheme, to minimize the design and construction costs without

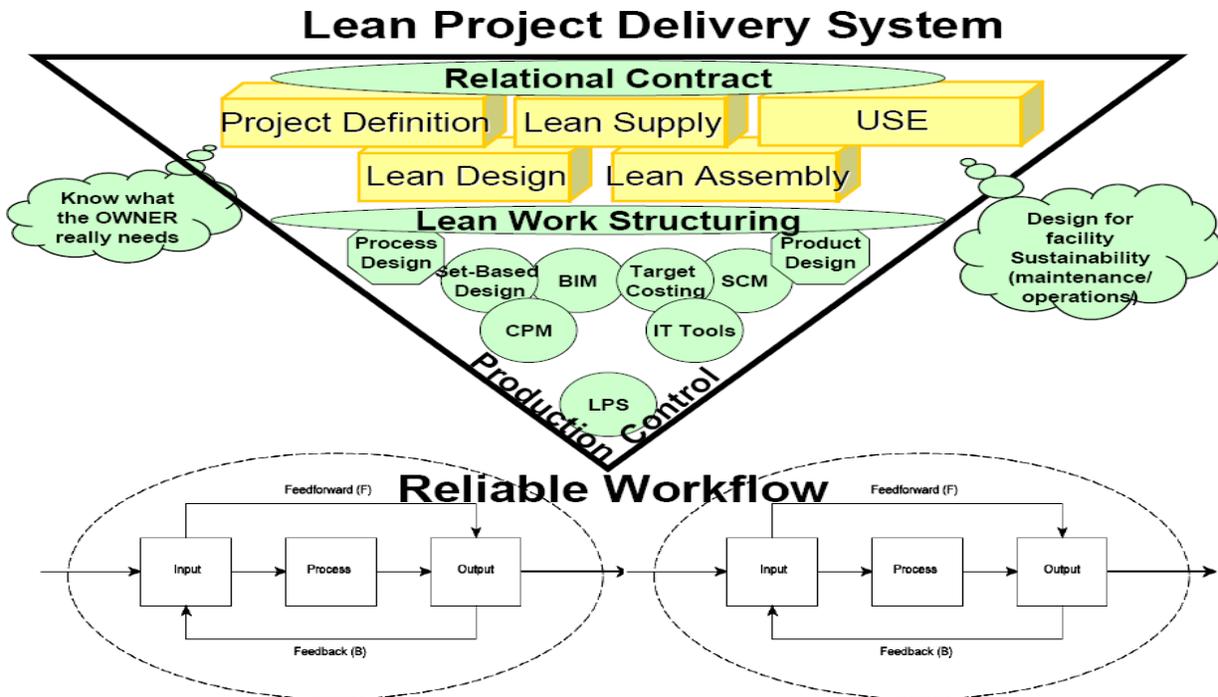


Figure 3. Lean Project Delivery System (Abdelhamid 2008)

sacrificing quality. Another highlight of this agreement is the sharing of incentives and savings by all parties proportionally, as agreed to by the team and in amounts proportional to the risk the part carried (Lichtig 2005).

Vanbots (Construction Management Company) and Honda (Owner)

Vanbots were selected by Honda for building their UK manufacturing plant at Swindon. Honda was very proactive in its approach and personally involved in all the decision making components of the project; they appointed Vanbots early in the project on the basis of quality, cost, delivery, management, safety and environment (QCDMSE) criteria. Honda invited Vanbots to value engineering sessions to decide on best solutions. Honda tackled conflict resolution issue by simply removing conflicts from the project using a pre-emptive approach; they instructed their subcontractors to give them early warnings about any foreseen problems and worked together to remove the potential reasons. They also used this approach to engage a commissioning team on their next project some 8 months before practical completion. The final cost to Honda was much less in the commissioning process as compared to previous projects, and also saved them considerable time in the handover

process to the occupants. Among other processes and features, the project utilized interactive smartboard technology to effectively communicate between parties at or remote from the site, visual communication boards throughout the site, and production planning. Honda reports that is saved \$50/m² on the construction budget compared to prior projects, and all participants (contractors, subcontractors, and suppliers) were satisfied with the project.

It is evident from the above examples and others being commonly reported now, that lean construction has proven benefits to owners, architects, contractors, and subcontractors that are deploying it. Michigan State University has the opportunity to be a leader amongst educational institution owners who adopt lean practices in their construction projects. The journey can begin with self-performed work and migrate to contract work.

Adopting lean practices demands behavioral change amongst all participants, from top-level management to bottom-level worker; this can be achieved by both regularly practicing lean and orienting new participants through discussions. MSU, being a prominent owner and a big educational institution in Michigan, can bring about this revolutionary change

through leading by example and educating its partners.

Development of capabilities will be a key aspect of implementation and success of Lean Construction conversion efforts. It must be recognized that lean transformations are not evolutionary but rather systemic, i.e., everything must change. Therefore, companies must be patient in implementation efforts and realize that benefits will take time to be fully leveraged. That's the essence of Lean Construction – the continuous and concurrent improvement and change of what we build and how we build it.

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