

IMPLEMENTING LEAN CONSTRUCTION: UNDERSTANDING AND ACTION

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ABSTRACT

Lean thinking is a new way to manage construction. Born in manufacturing, the goals demand a new way to coordinate action, one that is applicable to industries far removed from manufacturing. Implementation requires action be shaped by a deeper understanding of the goals and techniques. This paper explains the implications of the goals and key production principles, and how when taken together they result in a different way to manage construction. Implementing lean in construction then becomes a matter of developing and acting on this new knowledge. Advice on implementation is offered.

KEY WORDS

Lean construction, implementation, project management.

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INTRODUCTION

Lean thinking is a new way to manage construction. Many people object on first exposure because lean thinking appears to be the application of a manufacturing technique to construction. One response to the arguments that “construction is different” is to make construction more like manufacturing through greater standardization. We take the opposite view (Ballard and Howell 1998b) as we believe the goals of lean thinking describe the management of dynamic projects. But objections to lean in construction are hardly a surprise as lean was indeed developed in manufacturing, and individual tenets appear either already in practice or incomprehensible.

The goals of lean thinking redefine performance against three dimensions of perfection: (1) a uniquely custom product, (2) delivered instantly, with (3) nothing in stores. This is an ideal that maximizes value and minimizes waste. The goals demand a new way to coordinate action, one that is applicable to industries far removed from manufacturing.

The principles of lean thinking and production: (1) Stopping the Line, (2) Pulling Product Forward, (3) One-Piece Flow, (4) Synchronize and Align, and (5) Transparency, are techniques which support the goal. Implementation requires a deeper understanding of the goals and techniques. Some go astray by comforting themselves that they are already doing some or most of it, while those who believed going in that lean is about manufacturing want their money back. In this paper we explain the implications of the goals and key production principles, and how when taken together they result in a different way to manage construction. Implementing lean in construction then becomes a matter of developing and acting on this new knowledge. Simply put, but still only partly comprehensible in current thinking, lean is a value seeking process that maximizes value and continually redefines perfection as described above. Moving toward this form of perfection, requires more than a change in procedure, it requires changing the way we think about and do construction.

This paper first explains lean construction by exploring the essential differences between lean and current practice, then explores the underlying nature and implications of lean thinking. The paper closes with implementation advice based on this new understanding.

COMPARING CURRENT PRACTICE WITH LEAN

CURRENT PRACTICE

Construction management is activity or contract centered, with transactional contracts or assignments defining and balancing the objectives of various participants. Coordination between organizations or crews is primarily controlled from a central plan that establishes sequence and determines when an activity will start. Costs, errors, and learning occur within activities. Cost reduction results from improving productivity, and project duration is shortened by accelerating activities, or by changing logic to allow concurrent work. Waste is cost that could have been avoided within the activities, such as rework, or cost due to extended activity duration along the critical path.

LEAN PRODUCTION

Lean production presents a very different model. Production is managed so that actions are aligned to produce unique value for the customer. Project duration and cost are considered in “project-as-production system” terms making concern for project total cost and duration more important than the cost or duration of any activity. Coordination is accomplished in general by the central schedule while the details of work flow are managed throughout the organization by people who are aware of and support project goals (as opposed to activity or local) performance. Value to the customer and throughput, the movement of information or materials to completion are the primary objectives. Improvement results from reducing waste, that is the difference between the current situation and perfection, i.e., meeting customer unique requirements in zero time with nothing in stores.

Lean thinking forces attention on how value is generated rather than how any one activity is managed. Where current project management views a project as the combination of activities, lean thinking views the entire project in production system terms, that is, as if the project were one large operation. It is difficult to optimize a large production system in construction (a project) because of the complex interaction between the parts. Lean production principles, rules for organizing and managing production, certainly work in manufacturing. Once understood, they also apply in construction, if not directly then in principle. For example, lacking a production line in the manufacturing sense, we believe that planning at the assignment level is the place to “stop the line” in construction to assure a reliable flow of work through assembly on site. Stopping the line in manufacturing prevents the release of defective work downstream. Construction is directive driven in contrast to manufacturing which is routing driven. Planning is the place to “stop the line” by assuring no defective assignments are released downstream (Ballard and Howell 1998a). Stopping the line reduces uncertainty transmitted downstream making coordination much less difficult.

With this sort of expanded understanding lean appears to apply in any industry segment or situation. It can even be argued that manufacturing is a special case of construction because it alone is characterized by multiple copies of the same product. Both construction and manufacturing require prototyping, that is the design of both product and delivery process. Manufacturing is the special case because it alone moves beyond prototype to routine production.

Thus implementing lean production does not require making construction manufacturing by standardizing products, rather implementation starts by accepting the ideal of perfection offered by lean and understanding the application of each principle and technique to construction. Beyond these initial steps lies the development of new principles guiding the pursuit of the lean goal in the specific conditions of the construction industry. Implementing lean means adopting a “project-as-production-system” approach to construction, defining the objective in customer terms, and decentralizing management to maximize throughput and reduce inventories.

We also believe that implementation of lean in construction should start on projects. Lean developed on the operating floor and its implications spread throughout the organization and to suppliers. While processes may be improved anywhere with lean thinking, the project is always in the value stream of the client and the home office accounting systems rarely are.

IMPLICATIONS OF LEAN THINKING AND PRODUCTION

The tenets of lean thinking and lean production are drawn from *Lean Thinking* (Womack and Jones 1996).

Lean Thinking

Specify Value By Product

Identify the Value Stream

Make Product Flow

At the Pull of the Customer

While Pursuing Perfection -

Custom product, Zero time delivery, nothing in stores.

Lean Production

1. Stopping the Line

2. Pulling product

3. One Piece Flow

4. Synchronize and Align

5. Transparency

The first tenet, “Specify Value” appears to be part of current practice (and to an extent it is) but “stopping the line,” controlling work flow by “pull” and one piece flow” do not appear to be about construction. Designers can claim that their programming and design services produce specifications of value, just as those working in partnering relations can claim they are attending to project system issues instead of narrower interests. But these partial (and usually less complete than supposed) implementations come short as they lack the “pursuit of perfection” goal and the system focus brought by lean production techniques. On the plus side, partnering does establish a base level of trust which allows people within a system to shift their attention to improving at the system level instead of simply defending their interests. But trust is hard to maintain in the absence of reliable work flow. We believe trust between people requires system reliability.

It is worth reflecting on how lean thinking coordinates action. Specifying value by product to the customer shapes all actions around customer requirements. In construction, specifying value comes before design.

Identifying the value stream, the way value will be realized, establishes when and how decisions should be made. Mapping the value stream shows when the information necessary to meet owner requirements will be available and when it is required.

A value stream map is a comprehensive model of the project that reveals issues hidden in current approaches. Value stream maps can be understood as process flow charts that identify what action releases work to the next operation. Mapping brings choices to the surface and raises the possibility of maximizing performance at the project level. Normally maps are prepared at the project level and then decomposed to better understand how the design of planning, logistics and operations systems work together to support customer value.

The next principle, “Make it (value) flow” says that value development and therefore product components should be in constant motion, that is without stopping. This tenet supports the complimentary goals of zero stores and maximum throughput. Current practice ignores or accepts large inventories or backlogs as the natural consequence of the commercial situation. Lean works to eliminate those places where value adding work on material or information is interrupted. In construction this may mean repackaging work so that parts of the project can proceed without completion of others and/or assure that resources are delivered in order required directly to the installation location. We argue that current

construction planning systems are unable to produce a reliable flow of work (Ballard and Howell 1998a). Buffers or wasted capacity are the natural consequence of unreliable flow.

The current practice of urging speed at every turn results in large buffers because of the uncertainty associated with supply and use rates. Despite complaints about unreliable performance by other project participants, pressing for rapid completion is a common approach because people believe improvements within activities or changing the logical relationship between operations is the only way to reduce project cost and duration. Under lean thinking, improvement is possible by reducing uncertainty in work flow thus eliminating the need for intermediate backlogs. Redesigning the planning system at the assignment level is the key to assuring reliable work flow and must be an early implementation step.

“At the pull of the customer” means “make only what is sold.” In construction, except in speculative situations, this is already the norm as regards the facility as a whole. That is not the case, however, as regards facility components. Extending the concept of customer backwards from the ultimate user, the rule says that each production unit should make only what its ‘customer’ production unit needs. The intent is to avoid the waste of overproduction; i.e., doing work that does not release other work. Consequently, it becomes apparent that there are three types of inventories that need to be minimized, namely, (1) materials and design information, (2) labor and its tools, and (3) intermediate work product that is not being exploited. Attempting to exploit all open work faces is a partially conscious effort to minimize the latter type of inventory. However, the lack of conscious understanding allows that technique to be coupled with striving to start each activity as soon as possible. Early start in CPM terms reflects the urge to provide the most time for each activity, but is not governed by the intent to select work that releases other work. The concept of pull has different implications. The idea is that upstream activities should not start sooner than needed to assure the continuous release of downstream work. Thus “pull” assures flow in contrast to current construction practice which relies on the schedule to “push” resources. The application of Just-in-Time supply in construction requires activities to be coordinated by pulling. Push techniques controlled by the central plan, even in the more stable world of manufacturing, are unable to time the arrival of resources at the work face with enough precision to assure a reliable flow. In a sense, the CPM can be understood as a technique for pushing long lead items into the project parking lot or lay down yard. The resources are then pulled to their final location by an order from the field.

Pushing resources under even modest conditions of uncertainty means that resources must arrive on site before needed (often to support a degenerative form of flexibility properly called “slack resources”), or work may be delayed waiting arrival. Many in construction do not believe that a just-in-time (or more accurately, justified in time) (Daneshgari 1997) delivery is possible because they know close coordination is not possible using centralized scheduling, and cannot conceive any other means of coordinating action. Manufacturers have faced the same problem and now realize that pull is the only technique that will assure just-in-time delivery.

“Pulling” has been discussed above. “One piece flow” is the logical extension of pulling and flow. But what is a piece in construction? This principle is challenging as we tend to think and package work by trade while ignoring the way work is released. Projects are not

one piece—at least the interesting ones aren't—because the sub-assemblies have different work content, duration and types of connections with other units.

The rule to synchronize and align applies more easily and directly to construction. Consider two broad types of application. The first is the flow of materials from suppliers and fabricators to the site. Synchronizing the sequence and rate of delivery with the sequence and rate of installation is obviously valuable. Failing to do so causes both installation inefficiency and large inventories of materials on site. A second application is to a sequence of trades; e.g., finishing rooms of a hotel. Again, the need is apparent to synchronize the rate and sequence of work done by each trade. Otherwise, there are rooms ready to work lying empty, or crews are standing idle waiting on those ahead of them in the chain.

“Transparency” means that the state of the system is made visible to people making decisions throughout the production system so that they will take decisions locally in support of systems objectives. Transparency implies decentralized decision making which in turn, allows people to coordinate through mutual adjustment.

NATURE OF THE CHANGE

We believe that lean production is a new way to coordinate action that rests on a new mental model. Aspects of this model appear to be both sensible—Specify Value, and strange—Stop the Line. Problems solved by lean such as unreliable flow have been recognized as problems in construction, but no solutions are offered by common sense. Partial implementation of lean thinking, particularly organizational or relational aspects, have been developed and used on complex, uncertain and quick projects.

These dynamic projects are the ones most likely to fail when only traditional approaches are used. Lacking a comprehensive underlying theory, efforts such as partnering are little more than patches. Of course these patches are helpful when they lay the ground work for larger steps, but alone they do not fix the underlying problem, the design of the production system.

Lean thinking takes a project-as-production-system view as opposed to the current activity or contract centered perspective (Ballard and Howell 1998a). In this way lean embraces the uncertainty and complexity of construction and aims to assure that local improvements actually lead to results at the project level. But the shift from activity to system is a change at the mental model level that has important implications for implementation.

Peter Senge (Senge et al. 1994) says there are four levels of change: events, behavior, system (here used as “cost control system” or “logistic system”), and mental model. The industry is more or less adept at changes at the system or procedure level, and spends great energy trying to change behavior. Improvements at these levels are can be characterized as problem/solution, that is, there is some problem with the current procedure so we solve it. Change at the mental model level is different because each opens a new opportunity. Companies beginning to implement lean report an unexpected phenomenon; each change creates the opportunity for more and often larger improvements. Thus for a time it appears that the amount of change possible increases with each step of implementation.

Peter Senge offers general advice for managing a change at the mental model level in *The Fifth Discipline Fieldbook*. Dr. James Womack makes specific recommendations in *Lean Thinking* (Womack and Jones 1996) which are named and considered below.

Find a change agent: This is a person who makes things happen. Action is a must because it develops a new mind, and gives people confidence that changes can be made. Above all the change agent must have the courage to cause principle driven action, and to stand against attempts to dilute lean. For example, lean requires decentralized decision making. Decentralized decision making will be fiercely resisted by those who equate it to a loss in their power. Similar problems arise when a pull mechanism is installed to manage materials.

Get the knowledge: This means get enough knowledge to start and then continue to gain knowledge through implementation. A focus on system thinking is in order because it is uncommon in construction. Do not ignore the need to understand basic production management. Few universities offer courses in production management in construction and instead still teach courses in productivity improvement. Be cautious of such courses as a focus on productivity at the activity level and productivity reporting means you are missing the point of system performance. We join Dr. Womack in his advice that both change agents and senior managers must master lean thinking.

Find a lever by seizing a crisis or creating one: In some sense, every construction project is one crisis after another so this should not be difficult. We have had two different experiences worth considering. In one we worked on a large project with a series of subcontractors selected in the order of closest to be terminated. This is in line with one approach suggested by Dr. Womack of starting with a sub organization already in crisis. This approach can be successful but it makes the experience difficult to generalize to areas not in crisis. Worse, improvements which occur in crisis situations are often attributed to a failure to do it right on the part of one or more people. If people see the crisis in activity terms they will assume the problem is due to someone not doing their job, and not to a failure in the underlying systems. As a result, people learn little.

We propose an opposite approach: Start on the best projects. Application of lean thinking from the start with a good project team, or in the middle of a well run project underway reveals the weakness of current systems and the power of lean thinking. Mapping the project value stream usually provokes remarkable improvements as people see redundancy and waste as the map unfolds. In a sense, starting on the best is similar to Dr. Womack's suggestion to cause a crisis.

Forget grand strategy for the moment: While we agree that worrying why you were born is not useful, there are fundamental strategic implications in lean thinking. However, we believe that construction companies will want to start with work on projects. Because lean is a systems approach, finding opportunities and bottlenecks on projects first will reveal inadequacies in other areas which must be addressed to

assure maximum lean implementation at the project level. Projects are where we serve customers and it is on projects that we must improve.

Having said that, there is no reason to exclude home office or other functions from lean implementation. But we believe designing a supporting system to mesh with an inadequate project planning system is starting at the wrong end.

Map your value streams: Dr. Womack correctly cautions against relying on reengineering as it is often too narrow and lacks the sense of perfection that shapes lean thinking. In construction, the value stream inevitably involves other organizations and seeing them on the map is the first step to developing their participation.

Begin as soon as possible with an important and visible activity: We believe the production planning system and the way assignments are made is the place to start. No other activity is as important because changes in planning performance have both an immediate impact and reliable planning demands a lean response throughout the organization. Measuring and improving planning performance is a new idea in construction; it causes immediate improvement and reveals gaps in common sense.

Demand immediate results: We agree but with a caution. If you demand the wrong results you will destroy the lean initiative. Reduced costs within an activity are the wrong results to ask for, just as more rapid completion of tasks. Better to ask for immediate results in planning performance and for how such improvements translate into reduced backlogs between activities. Throughput measures are another good area for consideration. How much time has been cut from the time of order to delivery and delivery to installation?

Asking to review before and after value stream maps and/or changes in procedure are another way to assure changes are happening.

We support Dr. Womack's advice to avoid benchmarking, and we believe the recent resurgence of work sampling is a mistake. Data gathered by work sampling is aimed at improving performance of workers or crews by increasing the time working. But increasing labor utilization is not the same as increasing throughput. The pressure to increase direct work is likely to cause work to be released downstream in a less reliable flow as people adjust their behavior to improve their numbers. Making the numbers look good adds no value and provides measures of waste which are misleading. Such data is of no use in redesigning planning and logistic systems to increase throughput. Finally, work sampling maintains central control. In lean organizations, teams collect and act on their own data in support of larger objectives.

As soon as you have momentum, expand your scope: This advice is always worth remembering. The rate of change is the most important lean metric. If your effort is not causing action in all corners of the organization, if people aren't finding and making changes on their own, you are off track. Implementing lean always brings more opportunities to the surface.

OUR ADVICE

Implementing lean thinking will lead to change in almost every aspect of project and company management. No one step by step guide can be offered because change at the mental model level is a developmental process. Each principle driven action will reveal new opportunities hidden because people simply could not think in ways that made the change possible. Thinking causes action, action causes deep learning, and learning causes new thinking.

Take care to develop systems thinking, understand the difficulty of changing mental models, expect deep resistance in yourself and others to decentralized decision making, and learn about production management.

On the commercial side, begin to form long term alliances with like minds along the value stream. As a citizen of the industry, spend time and effort developing lean thinking in others, even competitors. More than one firm changing to lean has come up against the inability of their suppliers to support lean projects. Once on the way to becoming lean, these suppliers become almost schizophrenic as part of their customers work one way and the others lean. Expand your view to consider the construction industry as a system and work to improve performance everywhere. If this advice sounds wrong, it probably means you have not confronted the depth of opportunity and change lean offers you and your organization.

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