SELECTED ARTICLES FROM THE LEAN CONSTRUCTION CHRONICLE SPRING 1999

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Managing Construction: the Lean Perspective

Gregory A. Howell

The Lean Construction Institute (LCI) is a research organization with a very particular focus on production management, the way work is done, in construction. We are very different from other organizations because our first goal is to understand the underlying "physics" of production. This means we want to understand the effects of dependence and variation along supply and assembly chains. These physical issues are ignored in current practice and have no particular relationship to teamwork, communication or contract. These human issues are at the top of practitioner's lists of concerns because they do not, indeed cannot see the source of their problems in physical production terms.

The problem of matching labor to available work offers a good example of the difference between the contemporary view of the workplace and ours. "Matching labor to work" means having the resources on hand for a crew to work steadily and without interruption. Current practice views the assignment to a crew as a sort of "mini contract" which is more or less independent of other assignments, and sees the person in charge is responsible for the organization of resources and direction of the crew. To be fair, companies have logistics systems that try to get the resources close to the crew and a few actually try to assemble and assign packages of work. But the majority of foremen are responsible for the final collection of resources and assuring that their crews can work continuously. When this approach fails to produce acceptable results, when the numbers are bad, the assumption is that the foreman or crew isn't performing.

Companies typically maintain elaborate cost control systems to measure this performance. These systems are the manifestations of the cause and effect theories operating in the company. At the heart of this model is the belief that the crew is essentially independent and

that all costs charged to an account arise within from the effort necessary to complete the assignment.

Our view is different. We see the problem in physical production terms. The crew works at variable rates using resources supplied at varying rates. Matching labor to available work is a difficult systems design problem with a limited range of solutions. We can isolate the crew from variation in supply by providing buffers either in the form of large inventories of resources or excess capacity in the crew so they can speed up or slow as conditions dictate. These solutions are applied occasionally in practice, if without understanding. Unfortunately neither resource nor capacity buffers reduce the variation in supply and use rates of downstream crews.

In the factories of our dreams, this problem is solved by long and predictable product runs. Managers could know the work content at each station and balance the line to minimize imbalance. Such factories are only dreams. In construction we are making prototypes. We have some idea of the labor content of activities from previous projects but each project faces new production issues.

From the lean construction perspective" We embrace uncertainty in supply and use rates as the first great opportunity and employ production planning to make the release of work to the next crew more predictable, and then we work within the crews to understand the causes of variation. *Where current practice attacks speed, **we attack variation***. We balance work along a chain when we can get variation under control and match work content, and decouple through capacity or resource buffers when we cannot. Again, at this point we are talking about the physics of production. This means we want to understand how resources and information interact as they move forward through supply chains to site assembly and how the rate and variation of deliveries affect production. Where current practice assesses and attempts to control individual performance, we see the planning system as the key to reliable work flow. We use planning system performance measures to improve work flow reliability. These measures reflect our understanding of cause and effect. This is a different mind, a new novel. Once we understand physics problems at the crew level, we see all sorts of new issues. Once we understand physics of resource flow and work at the crew level, we see all sorts of new issues.

> Our first objective is to bring the flow of work and production itself under control. This means working to make work flow reliable. This effort pays immediate dividends and leads to deeper changes to better support reliable work flow. These include changing how work is structured early in design, and the organization and function of both the master project plan and lookahead process.

Human issues come into play on implementation. Contracts, team bonds, communications, these do not change the physics. They do limit what can happen. For example, the need for upstream investment to reduce downstream variation is in conflict with current practices of buying each piece for the lowest cost, or of pushing each crew to work quickly as opposed to reliably. Uncertainty in work flow places great demand on communication channels as people attempt to find some way to keep the project or their crew moving in the face of uncertainty. But flexibility defined in this way requires slack resources and injects more uncertainty into the flow of work. Where we see uncertainty as the consequence of the way we manage work, others see uncertainty as environmental and beyond their control; hence the helpless victim of fate arguments. We operate on different theories, we tell different stories.

Often the first question we are asked when describing a project is, "What kind of contract was this?" Next come organizational and systems issues: "Was supervision by area or craft? Union or not? Designers on site? Did the owner know what they wanted?" These reflect what we

call the “Contract mind.” We look for and ask about the way work is managed: How does the planning system perform? Does it produce reliable assignments?, Where are the inventories of resources and available work space and how big are they? In this way we move from task to system to organization to contract.

> We do advocate or prescribe taking immediate steps to stabilize work flow because we believe it is the best way to accomplish what people say they want, reduced cost and project duration.

We do not propose that we have one best way to manage a project, rather that there are issues to consider which have important implications for the way projects are managed. We are a research organization trying to understand the physics first. If we were doctors, we would be at the stage of studying anatomy and discovering that blood flows. Our prescriptions at this stage would be tentative and related to the obvious, “Apply pressure to serious wounds.” But we are hardly at the level of dietary prescription.

We believe we will change the world by understanding our little niche of physics. Our goal is understanding, not revolution for its own sake. We are troubled as a group by the waste of lives and resources caused by the current model. We think there is great profit to be made under a new one.

Lauri Koskela[1] has proposed that Lean Construction offers a more comprehensive way to think about construction than current models. Lean adds concepts of flow and value to the current emphasis on activities. I have made much of the physics and importance of reliable work flow. “Value” that is value to the client is one area of our work that does not rest so directly on some underlying physics. Here we are trying to understand how value is created. Our work will help organize and frame the conversation between ends and means so that the implications of decisions are more explicit. We expect the design process to change to better cope with the contending demands of uncertainty and speed, and to respond to the explosion in available technology.

So Lean Construction is not a productivity program at all. Rather it is a new way to manage production that leads to a new project delivery system. This new system incorporates important contributions from constructability, partnering, TQM and new forms of contract into a comprehensive new way to manage design and construction.

[1] Koskela, L., and Huovila, P., (1997). "On Foundations of Concurrent Engineering." Proceedings of the 1st International Conference on Concurrent Engineering in Construction, The Institution of Structural Engineers, London, pp. 22-32.

What is Lean Construction?

Greg Howell and Glenn Ballard

Lean construction is a new way to manage construction. The objective, principles and techniques of lean construction taken together form the basis for a new project delivery process. Unlike current approaches to managing construction (including design-build) and programmatic improvement efforts (partnering and TQM), lean construction provides the foundation for an operations based project delivery system. From roots in the Toyota Production System, this new way of designing and making capital facilities makes possible significant improvements on complex, uncertain and quick projects.

The Toyota Production System developed after the Second World War when Toyota was a small company. It was faced with the producing for a variety of cars for a small market and had only a small capital base. A production system was required that was capable of short product, rapid change to between kinds and models of automobiles, and the smallest amount of work in process possible. Engineer Ohno and other Japanese engineers were familiar with mass production of cars from their plant visits in the United States. Where US managers saw efficiency, Ohno saw waste at every turn. He understood that the pressure to keep each machine running at maximum production led to extensive inventories that he called "the waste of over production." And he understood that the pressure to keep the assembly line moving meant defects were built into the car requiring. Where the US approach aimed to minimize the cost of each part, Ohno's objective was to instantly deliver a product meeting a specific customer's requirements without inventory. This objective defines waste for any form of production, craft, mass or lean, and sets a multi-dimensioned standard of perfection that prevents sub-optimization. For example, instant delivery is possible from inventory; this is why we have pots of coffee. But the resources in inventory may not meet unique customer requirements, double-lowfat-decaffinated-latte.

Engineer Ohno began to develop the principles of lean production (as opposed to mass) as he redesigned the Toyoya production process. His relentless pursuit of perfection lead to the new form of production we call Lean[2].

Pursuit of perfection:

Waste is defined by the standard of perfection. Failure to meet the unique requirements of a client is waste, as is time beyond instant and inventory standing idle. The standard demands a new form of production management. Zero time delivery of a car meeting customer requirements, with nothing in inventory required that the rapid movement of each car down the line be tightly coordinated with the arrival of parts from supply chains. Rework would have to be eliminated as it reduced throughput, the time to make a car from beginning to end, and caused workflow to be unreliable. Eliminating unreliable workflow was key to both throughput and minimizing inventory. Ohno recognized that reducing the cost or increasing the speed of any one activity is likely to inject uncertainty into the flow of work and thus rarely contributes to increased throughput or lowest total cost. Rapid completion and low cost require high throughput resulting from matching the arrival of resources "Justified-in-time" with the flow of work.

[2] "On Foundations of Concurrent Engineering", Koskela, L, and Houvila, P. in Anumba, C & Evbuomwan, N. (editors) *Concurrent Engineering in Construction, CEC97*/ London, 3-4 July 1997. The Institute of Structural Engineers, London, 22-32.

A new view of the production system:

> Moving toward perfection starts with understanding the value stream, the way value to the customer is delivered. Once the value stream is mapped, the task becomes making work flow continuous and reliable. The final step is to improve the performance of each activity in ways that both add value and assure reliable flow, and then to repeat the process. By contrast, in mass production, as in construction, production is conceived as a series of activities, and efforts to improve are aimed at each activity with little concern for value or flow.

But how does the Toyota system apply in construction? Certainly the goal of a project meeting specific customer requirements delivered in zero time sounds like the objective for every project. And every project is unique, a product run of one, and all but a few are built under great cost and schedule pressure. But where the Toyota system worked to speed throughput and reduce inventories, the construction industry of today like old style manufacturing, aims to reduce the cost and increase the speed of each activity. Lean construction follows the Toyota model by working to optimize performance at the project level against a standard of perfection.

There are important differences between lean construction and current practice. In both approaches a design brief is prepared, the design developed and engineered and materials purchased, fabricated and installed. Under lean construction, the work in each of these activities is different and lean construction adds two essential concepts, works structuring and production control.

Design in current practice tends to be sequential, first primarily about what is to be built with considerations of how left for later or periodic constructability reviews. In lean, the pressure for zero time delivery demands concurrent design of product and process. Process design is the consideration of how the work is to be done; it structures the flow of work. This includes decisions about how the project will be broken into pieces and how the work in each piece will be coordinated with others. Work structuring requires input from those organizations whose performance is interdependent. This means some key procurement decisions will be made far earlier than in traditional practice, even design/build.

Production control applied over the life of the project is a second distinguishing feature of lean construction. Production control until recently has been developed and applied in manufacturing as distinct from construction. Production control consists of aggregate production planning, material coordination, work load control, work order release, and production unit control. The construction industry uses different terms and a different conceptual model than manufacturing.

In current construction practice, “planning” is the production of budgets, schedules, and other detailed specification of the steps to be followed and the constraints to be obeyed in the execution of the project. Once production begins, management devotes its efforts to “control”, i.e., monitoring of performance against those specifications, with corrective action as needed to conform performance. In manufacturing and lean construction, planning is defining the criteria for success and producing strategies for achieving them. Control is causing events to conform to plan. Control in manufacturing is conceived as the progressively more detailed shaping of material and information flows, i.e., the physical production process, to cause the desired future. Perhaps influenced by the fact that most direct production work is performed by specialists under contract, project and construction managers conceive control as the enforcement of contractual commitments, even when the ‘contract’ exists in the form of a division of responsibilities between units of the same organization. Where manufacturing control is forward looking. It

monitors and acts directly on the production processes and simply observes results, construction control monitors result and then tries trace back to cause to identify the party at fault.

The construction model of control is actually a model of project control or contract management, not production control. Control proper is causing events to conform to a plan. In the construction industry, direct control of production itself is conceived as occurring only within the production unit, and is not planned for in design or addressed by the disciplines of project or construction management. In other words, how the contractor, subcontractor, or department gets their activity done is their own business and is irrelevant as long as they meet their "contractual" commitments. Construction can thus be said to have no theory of production control proper.

This way of thinking is problematic. First of all, it is assumed that sufficient coordination of "contractors" (or activities) can be achieved solely by means of initial schedules and budgets; i.e., through defining, awarding, then enforcing commitments. Work order release, the immediate cause of action, is accomplished by "notices to proceed" with no significant additional coordination required among the "contractors" as they execute those commitments. This form of coordination is plausible only to the extent that the various "contracts" or work scopes are independent or simply sequentially dependent. It fails when activities are interdependent and or uncertainty is high. But construction is highly uncertain and interdependence is increasing due to new technologies and shorter schedules. Further, construction's objects are complex wholes such that the design and construction of their parts are necessarily interdependent one with another. Stability and predictability are actually the consequences of production control, rather than arguments against the need for production control. No theory of production control is needed in a construction world that is stable and predictable.

Lean construction is different from current construction management because it 1) has a clear set of objectives for the delivery process, 2) is aimed at maximizing performance at the project level, 3) designs concurrently product and process, and 4) applies production control throughout the life of the project. Current construction techniques attempt to optimize the project activity by activity and pay little attention to how value is created and flows to the customer. The reliable flow of information and resources and the release of work between activities, primary concerns under lean construction, are ignored in current construction practice.

Implementing lean construction is a developmental process that starts on a production control mental model. Key differences include;

1) Decentralizing decisions.
2) Controlling processes
3) Managing for throughput not point speed.
4) Improving Reliability.

Lean construction is a new way to think about and manage work, and these ideas are resisted as most new ideas are. Two common sources of resistance are worth discussing. First, in so far as the lean approach appears to coincide with current practice, such as its focus on foreman planning, people often dismiss lean as common sense. And since common sense must already be widely understood and implemented (or it wouldn't be common) there is no need further action. After all, we would not want our bosses to find we had no common sense, and in an industry long soaked in fault finding acid, not doing something right is dangerous (even if "right" has just been redefined). Resistance in this form is best managed by being clear about what is new, the contribution it will make and how it fits with current practice, and then assuring people that learning, growth and innovation are acceptable. Lean is still developing; even Toyota is finding more ways to improve.

The second form of resistance arises because much of lean construction is not common sense. In fact much of lean is counter intuitive on first reading. Emphasis on reliability throughout the production system sounds great until we say reliability is more important than speed or cost at any one point. (Typical cost schedule systems rest on the belief that speed and cost of each activity are primary concerns that are more important than reliable work flow.) Lean thinking shows that rapid completion of any activity does not assure rapid completion of the project. Even experienced thoughtful managers who want to adopt lean on their project find themselves pushing for increased productivity or production rate at the expense of reliability. But pressure for either increase almost always distorts the selection of work in favor of maximizing local performance (or in some cases simply the appearance of performance, "show pipe"). The reliable release of work downstream is lost to the demand for immediate, if local, performance. Lean is very strange because it puts the reliable work flow above local speed and cost. Where lean at first appeared to be common sense, it now violates common sense. Overcoming this form of resistance requires education and examples that show the counter intuitive nature of lean construction is more effective than current practice. (Any one who has ever learned to ski down hill understands how hard it is to overcome the intuitive urge to lean up hill. It takes practice, going slow at first, experimentation and more than a few falls and bruises.)

A more complex resistance to lean construction arises because organizational aspects of lean conflict with current if unstated principles. Current practice rests on an activity centered model that more or less ignores the flow and value issues. Managing the project delivery proces as a system is very different. System thinking always raises the issue of responsibility to new levels. Fault, if something fails, can always be found in activity centered thinking. But fault has a different meaning from a system perspective. In system thinking, failures are understood as information about the delivery process. In activity thinking, errors are evidence of a mistake. An example: The reason why work is not completed can be understood either in individual or system terms. The failure to complete assigned work in current practice is either the foreman's fault or whoever can be found to bear the burden. In system thinking it is evidence of a failure in the planning system which made it appear that the assignment met lean criteria and could be completed.

Lean also challenges the hierarchical nature of organizations. (This is related to the fault issue but with a different spin.) Lean decentralizes decisions. This doesn't mean foremen are now project managers but it does mean they have the duty to say "no" to an assignment which fails to meet agreed criteria. People who resist any move to decentralize decisions may believe lean diminishes their power. In our experience such people are unaware how many decisions already flows around them. Even so these people may be the last to join the lean revolution.

Finally, Lean is a new way to think about and do work in construction. Thought leads implementation; implementation sparks reflection and new understanding, and understanding more action. Identifying a change agent, getting the knowledge, mapping processes and installing reliable planning are the first steps to becoming lean. The transition takes time as each action in support of the ideal objectives creates new problems, benefits and understanding.

Common sense teaches us to break large problems into parts small enough to be solved. We believe "the devil is in the details", and he often is. Traditional research and science, like contemporary forms of project management, is built on this reductionist approach. The LCI research agenda does not ignore the details or the resulting common sense. But LCI is aligned with other forms of enquiry particularly the emerging science of complexity that attempt to understand how and why "The whole is more than the sum of its parts." It is here in complex uncertain and quick circumstance that we expect to make our contributions in construction, make explicit the roots of conventional wisdom and redefine common sense. This is not an academic exercise in the conventional sense. We develop theories and try them on real projects. This is action research.

LCI and Theory:

LCI is theory driven and theory seeking. We think nothing is more practical than a good theory, as it explains what happens and why. For example, in current practice a delay is often attributed to morally deficient subcontractors[3].

Our theory is that such delays may be due to the combined effects of dependence and variation working over a long supply chain and period. We can test this theory by experimenting with techniques that reduce dependence and variation and observe the results. New theory, that is new cause and effect models, are invisible to those holding current theories dear. We approach problems related to production in construction first in physical and then systems terms believing that issues of organization and contract can only be resolved by assuring they best manage the "physics" of production. This approach is in contrast with efforts that start with issues of motivation and contract and never to come to grips with the work itself.

LCI research projects are listed below. In each case we first want understand the current state of knowledge, and then form our theories. In this stage we must understand how the function is accomplished in current practice and the underlying mental model or theory that supports that practice. We cannot improve what we don't understand[4] so accurate description the first piece of the puzzle. Other pieces may be found in the literature, current practice, theory or practice in related fields or the application of logic while taking a shower. Once we assemble the pieces a new theory is revealed and we can design experiments and refine our thinking.

LCI Research Projects

1) Product design theory: how to understand and model the design process
2) Structuring work to facilitate value generation and flow management
3) Improving Planning reliability to 90%
4) Pulling materials and design information to site as needed

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[3] Of course the contractor may be but we cannot know unless the contractor is embedded in a principle based production system. By contrast we often see that behavior considered immoral is in fact a logical response to the failure in the underlying production system. Failure to provide labor to a project can be understood either as evidence of bad upbringing or overreaching opportunism, or as the best solution available in conditions of unreliable work flow.

[4] We mean here that current practice copes with the same physics as lean construction. We can't improve how we manage production unless we understand the basis for current practice and what it reveal about the nature of the problem. Don Schon said, "Practitioners know more than they can say." We try to provide the conceptual base and language so they can better understand their own techniques and how they might be improved.

5) Project Definition: how to develop design criteria for product and process.
6) Incorporating First Run Studies into lookahead
7) Mapping and streamlining supply chains for common materials and products such as Air Handling Units, structural steel, sheet metal, etc.
8) Cross Functional Teams/organizational aspects of concurrent engineering 3D modeling and product data management
9) Applying Last Planner to design
10) Concurrent Engineering: how best to integrate product and process design?

Executive Viewpoint: David Neenan
The Neenan Company

Executive Viewpoint if a column dedicated to giving voice to management perspective on industry topics. In this issue of the LCI CHRONICLE, David Neenan, Chairman and CEO of The Neenan Company, was asked to reply to the question, "Why do you believe that implementing lean ideas is good for your company?"

Owners and construction industry user councils say, "Buildings cost too much, take too long, and don't serve our needs into the future." Architects and builders keep pouring money into a dinosaur model called "Throw it Over the Wall." What good is partnering or high performance teams if the model is *divide and conquer*? Bucky Fuller used to complain that human beings were too specialized: that for us to see the forest from the trees, we needed to become "competitiveists." I believe we have over-specialized this industry and the time has come for a more comprehensive model.

If we look to the near future, structures will be built on virtual 3-D models and collision-checked numerous times before ground in broken. This will demand high-level interaction and integration from owners, designers, builders, subs, and suppliers. Superintendents will shift from the primary role of collision avoidance and putting out fires, to the role of planners. Designers and builders will invest in methods to integrate disciplines and eliminate waste. This has already happened in the manufacturing industry, and I think we're next. Just as we saw the automobile industry move from craft, to mass, to lean methods of production, we will witness the same evolution in the built environment industry. Those who get there in the first wave will be well rewarded by having the capacity to enhance their clients' ability to sustain competitive advantage, faster, better and with less cost.

At The Neenan Company, we have made the commitment to lean practices because we believe these practices support an operational strategy that keeps us focused on delivering value to our clients. People ask me, "What's this lean thing all about?" If I feared them as potential competitors, I'd say, "forget it." I don't, however, so I tell them that in two instances in this past quarter, we were able to almost double our field productivity. Do what you want; we will continue to invest in lean because we have found an approach that works.

Partnering and Lean Construction

Partnering was a response to a wave of litigation. Meetings brought together people who often never talked to one another over the life of a project and helped them to develop good enough relations to keep the dialogue open during construction. In well run meetings, all parties left with a sense of mutual obligation which was in contrast to the risk shifting and the urge to defend turf more frequently seen. Issues of trust were and are central in these meetings. Partnering has evolved but building a sense of team work and trust remain top priority. Implicit in these meetings was the assumption that trust and communication were the missing ingredients which when developed better assured project success. Partnering rests on a relational view of the industry.

Lean Construction takes a different but related view. Lean construction is about optimizing performance at the project level by designing the underlying planning and logistics system to be more reliable. Where partnering speaks of relations and trust, lean works on systems and reliability.

Trust and reliability are the human and systems design side of the same coin. We believe you won't trust me long if I am not reliable. Lean starts from system design and builds teams around those systems. This works better than trying to build trust first without some underlying basis for changes in behavior.

We now see partnering as a patch in the sense that litigation was only the surface problem. Some believe litigation resulted from a plague of lawyers and opportunists. Our reading is different. We believe partnering is evidence of a system of project management insufficient to the task of managing production on complex uncertain and quick projects. Having said that, partnering opens the door to significant improvement. We use the partnering process and meetings to design a planning system that works and to set in place the ability to measure and improve that performance. Partnering works when reliability and trust are built together.

LEAN CONSTRUCTION CONSULTING:
The Challenge to Change
Glenn Ballard, Lean Construction Institute

In FLAWLESS CONSULTING, Peter Block proposes three possible roles for a consultant: 1) the technical expert who tells people what to do to accomplish their stated goal, e.g., the tax expert who restructures accounting systems to maximize tax benefits, 2) the pair of hands—someone who temporarily functions as a member of the organization; e.g. the hired-gun HR manager brought in to handle mass layoffs, and 3) the facilitative consultant, who strives to help the client organization or individuals within it learn to do what the consultant knows how to do. LCI's consulting is *facilitative*. Our challenge is to help people learn to think, see, and act on a new mental model, the lean model.

Companies that are accomplished at self-transformation use consultants to get new ideas and to solve specific problems. Companies that are not so accomplished run the risk of substituting the hiring of consultants for actually making the needed changes. *In such cases, the consultant's real task is to help the company learn how to change*. That often involves telling unpleasant truths, and may quite properly cause the consultant to be fired. In such situations, the worst thing a consultant could do would be to act in place of company management. The consultant is always an outsider. As such, he or she can be rejected like foreign tissue when that is expedient. So acting in place of management does not cause change in the organization because it doesn't force anyone to learn anything.

As for making the lean transformation itself, there is much we still do not understand about it. However, LCI has long argued for starting with the Last Planner system of production control because that reveals areas needing improvement and b3ecause it releases the resources and energy for making those improvements. It also quickly runs companies up against old thinking and habits. Will they stick to their newly stated policy of making only quality assignments when pressed by client or contractor to put more men or equipment on the job? Will they be able to successfully deploy the new policy throughout the company so that design leaders and field superintendents do not blink when told that their assignments are no good; i.e., when the workers shut down the production line? These are moments of truth the consultant must help them prepare to face, but which then must be carefully monitored. The one thing we do understand is that inconsistency of speech and action torpedoes change initiatives.