

LEAN CONSTRUCTION AND EPC PERFORMANCE IMPROVEMENT

by

GLENN BALLARD

The conversion process model encourages suboptimization. One notorious example results from an owner insisting on keeping design costs below a certain percentage of total installed cost. A second example is the harmful practice of buying on price tag rather than cost to use, a practice much derided by Deming. A third example is the practice of controlling manpower quantities as a sole or primary means for achieving schedule.

The mismanagement encouraged by the conversion model clearly can infect any or all of the phases and functions involved in a construction project; the design phase, the procurement phase, and the construction phase proper. This paper explores the consequences for performance improvement strategies of displacing the conversion model with lean construction concepts and principles.

The inadequacy of the conversion process model is especially apparent in regard to projects in which engineering, procurement, and construction overlap in time, i.e. "fast track" projects, the norm in industrial plant construction. How is it reasonable to restrict design cost to a maximum percentage without taking into account the downstream impacts of design quality on plant performance and cost to construct?

Strange as it may seem, such suboptimization is the rule rather than the exception. Our ways of thinking about and managing EPC projects appear to have been formed in the 'good old days' when each phase was performed sequentially. The designer produces the design, including equipment and material specifications. Equipment and material are purchased and delivered to the plant site. A construction contractor is selected to assemble the equipment and material into the desired facility in accordance with the drawings and specifications from the designer. This non-overlapping sequence encouraged the misconception that each phase could be

considered separately, without regard to interdependencies and tradeoffs.

The shift to concurrent design, procurement and construction strains the assumption of independence, especially because of the obvious need to integrate the work activities of each phase within a single unified schedule. The examples from the automobile industry of lean design, lean supply, and lean manufacturing are now joining up with the already strained assumption of independence. Old concepts and new fight for supremacy as we move from the old paradigm to the new.

These initiatives pose interesting questions for the development of "lean construction":

- What is the optimum investment program?
- How to take into account the interdependency of functions?
- Is it smart to invest in the front end and realize the gains on the back end? If so, how?
- How bring the entire process under control--the prerequisite for breakthrough to new performance standards?

In one case, the strategy is to pursue changes in three steps, beginning with controlling each function, then investing in design quality, supplier delivery, and construction cycle time reduction, in that order.

Engineering is a supplier to Construction; supplying drawings and specifications. Engineering supplies Procurement with requisitions detailing what equipment, fabricated items, and bulk materials need to be purchased and what specialized services need to be contracted. External suppliers and service providers are suppliers to Construction. Construction is obviously a supplier to the owner of the facility. The model for understanding the interdependency of these functions is the simple supplier/customer model.

In accordance with that model, it is apparent that the quality of design (the quality dimension important to construction is design constructability, document clarity and consistency, dimensional accuracy, etc.; not the performance capability, operability, or maintainability of the plant) and the reliable delivery of resources

to the construction site are critical inputs to the construction work process.

What happens when the delivery to Construction of an external resource is erratic? Chart 5 displays the percentage of drawings and specifications that were issued past scheduled milestone dates. On average, more than 30% of engineering deliverables were behind schedule. What's more, the average days late was 56.

Interestingly, the project was completed on time, on budget, and to the entire satisfaction of the owner. Does that mean the late delivery of engineering drawings and specifications had no impact on the project? I suggest that current schedules and budgets assume that such poor performance will occur. In short, current standards of performance include tremendous amounts of waste.

In order to explain the importance of reducing variation in resource delivery, I must introduce a few concepts. First, the essential elements of a planning system are those that determine what should be done, what can be done, and what will be done. In my experience in the construction industry, we usually do a good job with "should", a mediocre job with "can", and a very poor job with "will". The front line supervisor, whether foreman, squad boss or purchasing supervisor, does his planning based on information he receives regarding "should" and "can". His job is to approximate "should" within the limits of "can", thus producing assignments that are practical, and providing reliable input for the planning of interdependent work processes. Where the commitment to what will be done is made within the organization, and how much in advance of the plan period, varies from project to project. When directives are contradictory or resource information is faulty, supervisors give up on crew level planning, coordination disappears, and performance deteriorates. Assignments become mere expressions of the original schedule, untempered by resource availability. Too frequently, craftsmen spend most of their time trying to determine whether or not the assignment can be carried out.

It is obviously preferable to produce good assignments, and that means enabling the Last Planners in each constituent organization.

The Last Planner is last in a chain of planners, each providing directives ("shoulds") to the next. Construction is complex. Planning is not done by one person or group at one time. It is distributed

throughout the organization and over the life of a project. The "last planner" is the one who produces directives that drive direct work processes, not other planning processes; i.e. assignments. If the planning system fails to produce good assignments, it does not matter how good the upstream planning was. Those plans never get realized.

I am now attempting with several clients to shift the control focus closer to root causes by monitoring the "percent plan complete" at the Last Planner level. Initial measurements show percentages from 35% to 50%.

As we analyze and act on the causes for incompleteness, those percentages rise, and productivity and production rise along with them.

Eliminating root causes can require the redesign of planning and control systems, coaching and training of planners, redistribution of information, as well as improvements in the physical distribution of resources such as materials, tool and equipment.

In the case illustrated here, insufficient and inadequate materials account for 40% of plan failures. Consequently, we chose to work first on the materials system.

Returning to the strategy for EPC performance improvement, it is thought necessary to first bring all work processes under control, in order to provide the conditions in which substantial improvements can be made. In this instance, "in control" means able to keep commitments and standardization of processes; especially as regards delivery of inputs to downstream customers. The strategy for achieving control is to identify last planners, clarify their role and expectations, and enable them to be successful.

Step Two for Engineering is to improve quality. Step Three is to reduce the duration of the design phase. Quality comes first because of its impact on the time and cost of Procurement and Construction.

Let's look more closely at Engineering's Step One. "Release time for investment..." is a way of shielding the Last Planner from an erratic flow of resources, and may appear to be in contradiction with the principles of Lean Construction. Shingo declares the goal in his term

"non-stock production", while I am advocating the deliberate creation of inventory surge piles. The goal is the same, but to get there requires freeing management time and energy for improvement. The strategy is perhaps counter-intuitive, but, inverting Lenin, one step backward does lead to two steps forward. Reducing uncertainty at the Last Planner level reduces the amount of time supervisors spend hustling resources and fighting fires, and results in more in-process inspection of work, more coaching and innovation. We cannot reasonably expect those on the firing line to work on making improvements as long as they must struggle to simply get the work done at all.

When I first began research with this contractor, they were consistently unable to meet design schedules. Investigation revealed poor goal setting as one cause. Senior managers made whatever commitments were needed to win work; admittedly with some reliance on historical project durations. Often there would be meetings early in the project in which engineering management (project, process, mechanical, civil, structural, piping, electrical, and instrumentation) would develop a design schedule. The first attempt would be much too long, so each manager would cut some constraints. "You don't need certified vendor data to estimate horsepower requirements! That's what you get paid for!" A rerun of the logic network would reveal a shorter duration, but still too long, so more constraints would be cut. Eventually, the managers went beyond their ability to understand and manage the risks resulting from their decisions. The consequence was an erratic flow of work, a deterioration of detailed planning, and gross schedule overruns. Construction was usually able to absorb the late and out-of-sequence delivery of drawings and materials to the jobsite, but at a tremendous cost.

To make better decisions about process logic, the contractor has begun an analysis of past projects grouped by type of facility being designed. While producing a roadmap to guide decision-making, they are also collecting workaround strategies, i.e. strategies for managing the risks attendant upon cutting constraints. One example is redundancy; e.g. size all starters at the top end to accommodate the greatest possible horsepower range.

A related issue here is the harmful substitution of progress planning and control for schedule planning and control. In industrial facility design, the control focus is not on producing the right output at the right time, but on producing the right amount of output, usually measured in terms of earned manhours. Perhaps the erratic flow of work caused by pressure for speedier production has led people to give up. Unfortunately, controlling progress rather than schedule makes it even more difficult to achieve schedules.

Turning now to Procurement, the first step is to develop the tools needed for performance improvement. The second step is to reduce delivery variation and cost. The third step is to reduce the time required to produce and provide goods and services.

Again, duration is the last target, and again for the same reason. The greater impact on total installed cost and total project duration is from erratic, unreliable delivery. In addition, the reduction of uncertainty is the precondition for improvement. What's more, the reduction of procurement durations requires prior investment in technology and in relationships.

This contractor has invested in an integrated materials management system. That means they can generate purchase orders directly from requisitions, the purchase orders show up on the Expediting and Supplier Quality modules, and the same data supports job site receiving and issue. The intent is to avoid handoffs across functional boundaries as a product progresses through the project cycle, all the way to installation and use (or disposition of surplus).

They are also implementing a supplier quality process and developing supplier alliances. Last but not least, they are beginning to get the facts regarding procurement processes and supplier performance.

One example is this control chart showing the delivery of structural steel over a nine month period. The range is from 13 weeks early to 11 weeks late. This reduced craft productivity, not only for structural ironworkers, but also for the electricians, who were forced to pull wire and cable within a shorter duration because prerequisite work was not completed on time.

Like Engineering and Procurement, Construction's first task is to minimize the impact of poor quality and timeliness of inputs from others. Again, the last target is reduction of durations, which

requires for substantive gains prior improvement in the flow of design documents and materials. While waiting for such improvements, Construction can capitalize on a more stable environment and tackle cost reduction in Step Two.

The key here is to make the foreman a manager rather than a gang pusher. As discussed previously, that involves enabling the foreman to act as a Last Planner.

Actually, Step One also includes some cost reduction, i.e. reduction of delays, which reduces non-productive time and improves productivity. When the flow of drawings and materials is off schedule, productivity will deteriorate. However, the damage can be minimized by insuring that assignments are material-sound and can be done.

The magnitude of delays on large industrial projects is indicated here, with approximately 25% of direct labor time lost, and that was on projects at the good end of the range. (This data is from craftsman questionnaire surveys.)

I use a systems graphic language I call "Workmapping" to display the interdependence of processes. The focus of this one is field planning, shown producing assignments that drive direct work, which in turn consumes resources including labor, materials, tools and information. Also shown are the control/breakthrough diamonds representing processes that answer the question, "Do we need to change?" Change can be a return to an existing standard of performance (control) or the introduction of a superior performance standard (breakthrough).

Moving to Step Two, this lists some key actions Engineering needs to take. Obviously, the supervision time released in Step One needs to be invested. The choice made here is to invest in error reduction and in determining customer wants.

Customer wants are not restricted to the proximate customer, usually someone from the client's home engineering office. Also included are the construction contractor, and client marketing, financial, operations and maintenance personnel.

Value engineering can play a helpful role if modified to address not only the cost to accomplish necessary plant functions, but the other phases and dimensions of the entire plant life cycle as well.

One more aside: There is a great temptation to seize on the one change that will yield a competitive advantage. Unfortunately, there is no one thing. There are many changes needed and they are themselves interdependent, so cannot be successfully implemented out of sequence. This is very frustrating to most American managers. The solution is to actually understand how work processes fit together within a supplier/customer framework. Procurement has two tasks in Step Two: To reduce delivery variation and to reduce cost. Both are pursued by implementation of the tools developed in Step One, i.e. the integrated database and the supplier quality process.

This is an area where the construction industry can most completely (although till not entirely) imitate manufacturing. According to the book, The Machine That Changed the World, even U.S. manufacturing needs to redesign contractual relationships to align supplier and user interests to continuous improvement. That is more difficult in Construction, but still can be done. For example, fabricators are usually inadequately compensated for production and delivery that interrupts cost-saving long production runs. One part of the solution is to change contracts so they are compensated. Another part is to change fabrication shop processes to reduce the cost of producing shorter runs. For the most part, U.S. suppliers are still in the mass production mode. Large owners and contractors can facilitate their transition to lean production. Step Two in Construction is focused on cost reduction, and assume the stabilized environment created in Step One.

I have been working closely with several contractors during the construction phase of EPC industrial projects. My first observation has already been stated several times regarding the disruption and waste caused by poor quality and delivery of offsite resources, specifically design documents and permanent plant materials and equipment. A second observation is that the construction industry is in some ways not completely shifted from craft to mass production-- much less to lean production. The absence of industrial engineers

from project sites and the lack of standard work methods is one sign of the dominance of the craft production model--no little assisted by the contention that each facility is unique. On the other hand, the industry has followed the mass production model in its extensive division of labor; a phenomenon even more characteristic of merit shop projects than of union projects. The worker who can move from carpentry to pipefitting is extremely rare, as is the worker who can build formwork and do finish carpentry. The trend has been to assign specialists to each type of work, and attempt to coordinate the work activities of these specialists by increasing the number and layers of supervision. Consolidating specialty functions into single points of responsibility and eliminating management layers is much needed.

Another area of opportunity is inspection and rework. No one, as far as I know, really understands what percentage of craft manhours is devoted to rework of various kinds. My guesstimate is 25%. Much of that will be eliminated by releasing supervisors to supervise. In addition, there must be aggressive steps taken to accelerate learning from experience and to reduce the number of back-to-back inspections. To enable these changes, it will be necessary to convert quality inspectors from policemen into teachers, and to convince those making errors that it is safe to report them; i.e. that the root cause of errors will be eliminated, and not the messenger. At this point in time, the strategy for Step Three is least developed. These are some of the components.

Concurrent engineering is the primary model and engine for reducing project duration. In addition to the aspects developed in manufacturing, the construction industry needs to understand how to execute the work of interdependent engineering disciplines simultaneously, as well as simultaneously addressing all life cycle design criteria. One idea is to apply both technological and organizational tools developed in manufacturing, i.e. electronic data interchange and cross-functional teams. Even though engineers are assigned to large projects under the control of strong project managers, in a task force mode, there remain tremendous problems coordinating across disciplines. The contractor implementing the strategy I have presented may experiment with mixed teams, with

joint responsibility for a set of interdependent deliverables, and considerable autonomy at managing the internal interfaces.

Procurement can reduce the time required for acquisition of resources by eliminating wasted time in information flows, reducing transport distances by selection of local suppliers (or the more expensive use of local staging areas), and by the use of blanket purchase orders that get some steps in the cycle done ahead of time.

In addition, Procurement must work with Construction on timing of deliveries. The goal is for Construction to release resources for delivery just when needed. This reduces on-hand inventory, space requirements, and double handling when equipment and materials can be placed directly into final position off delivery vehicles.

As delivery variation declines, Construction can reduce the size of backlogs required to initiate work, thus advancing construction mobilization. In addition, there will remain opportunities for squeezing time from construction processes--primarily from better coordination of interdependent crafts. Better coordination can be achieved by the same strategy used in Engineering, i.e. subprojects with cross-functional teams. In cases where a substantial part of the work is subcontracted, the contractual relationship will require redesign to facilitate teamwork.

To conclude: The conversion process model would have us attempt to achieve performance improvement on EPC projects by separately reducing the cost and time of Engineering, Procurement and Construction, without regard to their interdependencies. The lean construction model facilitates EPC performance improvement by revealing those interdependencies.

The strategy pursued by one U.S. industrial contractor begins by implementing the Last Planner Concept as a means of shielding the direct work force from variation in resource flow. This releases energy and time for reducing quality and delivery variation, i.e. investment is made in design quality, supplier delivery and construction cost reduction. This provides the basis for substantial reductions in project duration, largely from accelerating site

mobilization as deliveries become more reliable and inventory requirements fall.