



Using Lean Design and Construction to Get More from Capital Projects

By Michael Bade and Christine Haas

The University of California at San Francisco has experienced significant benefits from using Lean design and construction compared to its experience with traditional capital project delivery methods.

The University of California San Francisco (UCSF) has been using Lean construction methods since 2007 to effect improvements such as consistent on-time delivery; avoidance of claims and costly adjudication; competitive, predictable costs; and improved design and building performance. The approach works by applying Lean management principles and concepts to the design and delivery of capital projects. First employed on private-sector projects such as industrial plants and hospitals, these ideas have started to show their value in the design and delivery of complex projects for the public sector over the last decade. Examples include the State of Washington, the Massachusetts College of Art and Design, and the U.S. Army Corps of Engineers.

Lean construction identifies what is valuable in a construction project and studies existing work processes to remove waste. Six Lean principles guide the modifications:

1. Identify value from the point of view of the customer.
2. Understand the streams of work by which value is delivered.
3. Achieve a smooth flow within work processes as waste is removed.
4. Employ pull planning¹ so that nothing is made or delivered until it is needed.
5. Make continuous efforts to improve existing processes.

6. Develop and use applied technology to improve access to and use of information.

ESSENTIAL FEATURES

Lean design and construction differs profoundly from traditional approaches to project management.² What distinguishes Lean is that it takes a scientific approach to product and process improvement — one that tries to constantly improve on the recipe. The essential feature of Lean is that the production environment is much more closely coupled with the preproduction. Also, the independence of the production environment is nurtured by making it easier to solve problems as they arise downstream.

Traditional project management strategies attempt to optimize the project by:

- Isolating activities and optimizing each one, assuming that customer value³ has been defined in the design phase (which takes place prior to the construction phase, and is minimally informed by construction phase participants).
- Breaking the project into logical, sequenced components and estimating the time and resources for each activity.
- Developing a separate contract for each component, wherein it is individually monitored against schedule and budget projections.



The Smith Cardiovascular Research Building, which used a Lean construction manager at risk contract with design-build subcontractors, was finished three months ahead of schedule and more than \$5 million under budget.

With traditional project management, if specific activities or sequences of activities run into problems or fall behind, efforts are made to isolate the problems, often by trading cost for schedule. To the extent that problems cannot be addressed successfully within this framework, disputes and litigation often arise.

For example, on a traditionally managed cogeneration plant construction project, a delay in procuring steam turbines will likely delay the delivery and installation of those turbines as well as the overall commissioning of the cogeneration plant. There is a domino effect; if one component encounters roadblocks, the entire project suffers. If Lean tools like pull planning scheduling and just-in-time procurement had been used instead, the additional cost and time could have been wholly avoided.

Focusing on the Big Picture. The Lean approach to design and construction addresses both the design of the project and the processes by which the project will be realized, identifying the customer's objectives for the project

and eliminating each element of the process that does not add value. Design and construction are understood and organized as a single, intertwined, continuous flow of work. The project team seeks to perfect the overall process and create a reliable production flow across the entire process, rather than isolating individual activities and focusing on the productivity characteristics of each element of work. In other words, the idea is to optimize performance at the project level, not on an individual, component-by-component basis.

One fundamental lesson of Lean production management is that process components cannot be managed individually. Each component affects other components; they are all interrelated, not separate entities. These impacts include costs, which traditional project management typically passes to the owner as change orders tied to schedule delays.

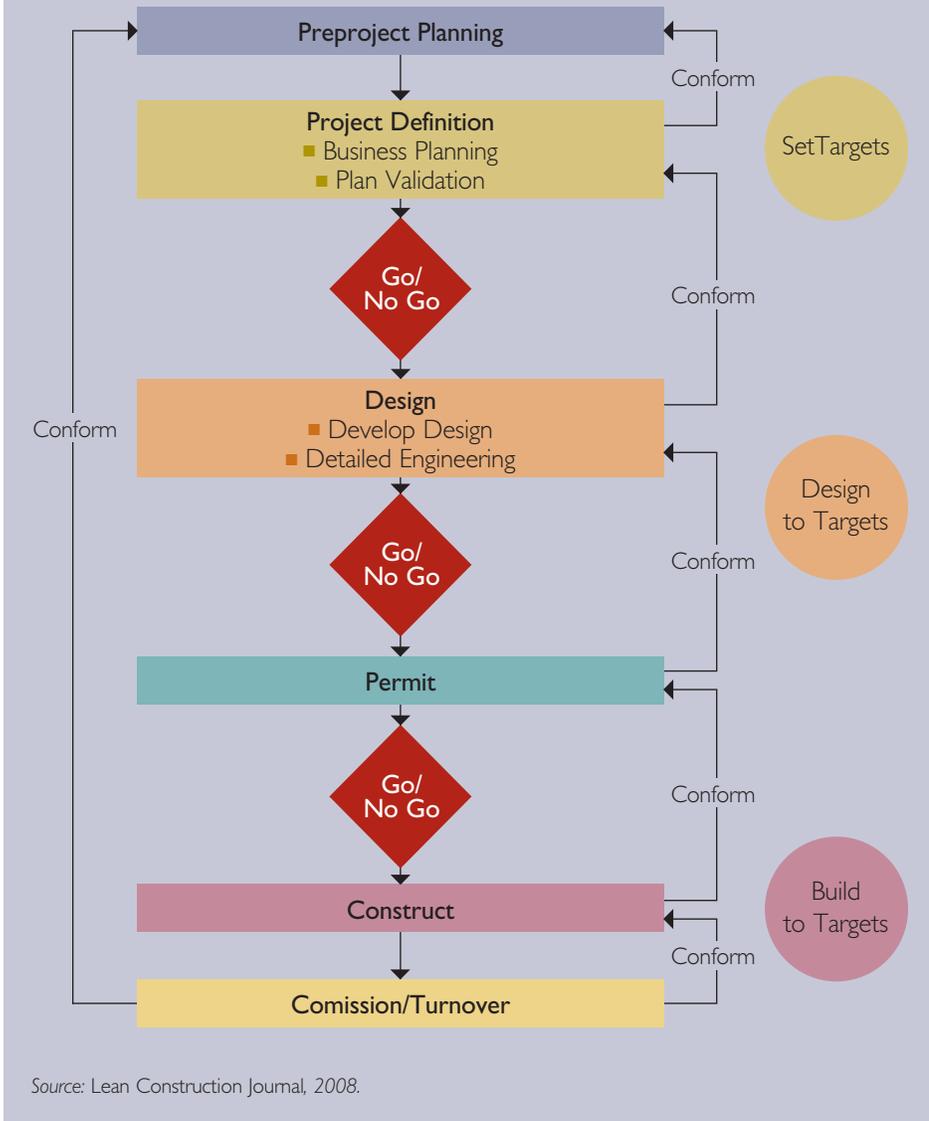
Tolerating Inefficiencies. Lean management principles even tolerate inefficiencies at the individual component level if they contribute to optimization of production on the whole project. Collaboration between the many entities participating in the project is seen as critical to its success, as project production systems are essentially complex chains of cooperating entities performing work over time, each of which contributes to the creation of customer value at the project level. Creating reliable workflow at the project level helps eliminate a major source of waste, including waiting, overproduction, rework, moving people or things around, producing work to a higher specification than the job demands, and having too much or too little inventory.

Identifying Downstream Stakeholders. How does Lean differ from, say, Project Management Institute (PMI) standards? The essential difference is that the PMI project management does not reach into production management. Its focus stays at the level of the project leadership, rather than getting down to the level of the people doing the work on the ground. The Lean approach is more disruptive, and more self-critical. According to Lean principles, downstream stakeholders must be involved in planning and design, and remain involved throughout the construction process. Using target value design procedures,⁴ desired outcomes can be embodied in the design of the project, while simultaneously configuring and managing production processes to attain those outcomes. (See Exhibit 1.) In other words, the focus is on managing the flow of information, materials, and the personnel necessary for design and construction throughout the project, and absorbing variability by using strategic inventory buffers and productive capacities within the overall supply chain.⁵



The largest project the University of California has ever built, the UCSF Benioff Children's Hospital, was delivered on time and on budget, with no claims, using a Lean cost-plus contract.

Exhibit I: Project Phases and Target Value Design



Adjusting Work Flow. Feedback loops are built into every level and process of the project to generate the information needed for continuous process improvement. Pull planning techniques are used to govern the flow of work from upstream to downstream, in order to correctly time the flow of information, materials, and human expertise within the overall project workflow. All project participants take part in continuous process improvement activities to create a reliable work-

flow, avoid rework, and identify and eliminate waste. Whenever possible, processes are designed to be mistake-proof. The project participants who are responsible for doing the work in the design- and production-control systems are allowed to make decisions as needed, rather than having to go back to one central authority.

In contrast, traditional project management does not consider the interaction between activities in the production sequence because these are

conceived separately, in isolation from each other. Information, schedules, and techniques are pushed down from above, which results in mistimed flows of information and materials, which in turn creates rework, excess inventory, or both. According to Lean principles, this is why complex projects so often run into problems — the methods themselves generate issues because the leadership and production levels of the project are inadequately joined, and the production level does not have the opportunity to adequately organize its own workflow.

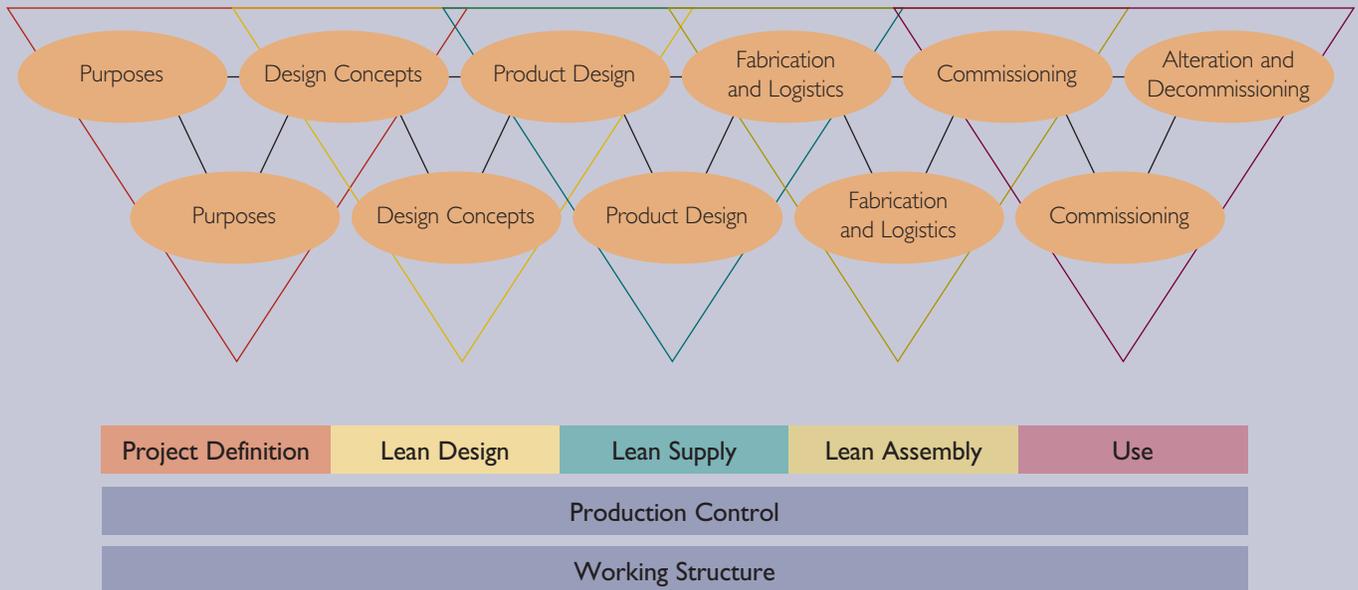
Glenn Ballard, director, Project Productions Systems Laboratory at the University of California at Berkeley and one of the founders of Lean construction, developed a graphic that shows Lean project implementation as a series of overlapping phase domains organized in a semi-linear process. Not only do the phase domains overlap, but they are connected by recursive loops that reflect learning and process improvement within the project. (See Exhibit 2.)

CHOOSING LEAN

UCSF is a health sciences university with an active 10-year capital program consisting of new and renovated hospital and laboratory facilities, dry research buildings, housing, and an extensive seismic renovation program. UCSF has used Lean design and construction principles for selected capital projects since 2007. Lean has been used successfully in complex projects valued at more than \$2 billion.

In the late 1990s, UCSF began developing a new research campus at Mission Bay in southeastern San Francisco. The first group of new build-

Exhibit 2: A Lean Project Delivery System



Source: Lean Construction Journal, 2008.

ings used traditional design-bid-build⁶ and simple construction manager at risk⁷ delivery methods, and the university experienced project schedule delays, unplanned costs, disputes and litigation, and quality issues because of



The extremely complex Anatomy Teaching Laboratory project, which used a Lean construction manager at risk with design-build subs contract, was finished on time and on budget.

the method of construction delivery. As a result, in 2004, UCSF started looking for new delivery methods that could avoid these issues.

In 2007, two new delivery models were developed using best value contractor selection⁸ and Lean design and construction methods. UCSF used a Lean design-build delivery model, which used performance criteria, and a Lean construction manager at risk delivery model, which employed design-build subcontractors for critical trade packages.

UCSF selected teams of architects, engineers, contractors, and tradesmen who could use Lean tools to improve the process and the built product. The university adapted its contracts to require that Lean construction tools be used during design and construction. UCSF

supported these efforts in myriad ways during day-to-day interactions, setting clear, inviolable goals and making the information used in the design and construction process as dependable as possible. This is the owner's responsibility, and failing to meet it is the single largest source of delay and rework in a construction project.

UCSF has experienced significant benefits from using Lean design and construction compared to its experience with traditional capital project delivery methods. Improvements include consistent on-time delivery; avoidance of claims and costly adjudication; competitive, predictable costs; improved design and building performance, crisp and effective start-up and commissioning; and improved end-user satisfaction.

LEAN CONSTRUCTION AND THE PUBLIC OWNER

UCSF follows California Public Contract Code provisions when implementing capital projects, but unlike some states, California code does not narrowly dictate forms of project delivery. The university can use design-bid-build, construction manager at risk, cost-plus, design-build, multiple-prime, and job order contracting for project delivery. Multi-party agreements such as those found in the private sector, however, are not permitted. California law does allow for prequalification of contractors, which UCSF advocates and uses whenever possible for its major projects.

UCSF has developed three Lean delivery models: a Lean design-build contract, a Lean construction manager at risk contract, and a Lean cost-plus contract.⁹ Both the construction manager at risk and cost-plus contracts employ design-build subcontractors for key trades such as mechanical, electrical, plumbing, fire protection, and exterior envelope. All UCSF Lean delivery models require that vendors use Lean tools and processes to deliver projects. Each delivery model is implemented with comprehensive prequalification processes to ensure that the bid pool is made up of contractors that can do so.

Identifying Value. The use of best value contractor selection has been a key ingredient in the success of UCSF Lean construction delivery. The state legislature allowed UCSF to use best value on a pilot basis starting in 2007, with a five-year term for the initial pilot period. This pilot was extended to the other nine campuses in the University of California system when the pilot was renewed in 2012.

Using best value allows the public owner to employ a structured evaluation process to grade prequalified contractors based on their answers to a detailed questionnaire submitted at the time of bid. The questionnaire is evaluated and points are assigned before the formal bid opening. The law requires evaluation under five subject areas — management competency, financial capacity, safety record, labor compliance, and relevant experience. The score is then divided into the amount of the bid to develop a cost per quality point for each bidder, and the lowest cost per quality point is the basis for awarding the project. This is not always the contractor that submitted the lowest bid.

For public agencies like UCSF that build complex, mission-critical facilities, best value selection has been a game-changer. The most competent contractors, which usually only pursue negotiated work with private-sector clients, now pursue public projects that use best value selection.



Photo: Bruce Damonte

Using Lean management techniques, the Ray and Dagmar Dolby Regeneration Medicine Building overcame a five-month delay in completing foundations and site work on the complex site. The building was finished in 14 months — on time, with excellent quality and no contractor claims or lawsuits.



Mission Hall, a dry research/office building on the Mission Bay campus that was delivered using a performance specification-based design-build competition, was built at a competitive cost while achieving an enhanced level of structural and seismic performance.

Understanding the Streams of Work. Traditional project delivery in the public sector has developed a reputation for chaos and frequent delays that pushes the risks of project execution onto the public institution's business partners. In seeking to ameliorate such risks, public institutions need to be ready to perform controlled experiments, listen to their business partners, and take their concerns to heart. For example, UCSF has found that establishing dispute resolution panels where the occasional grievance can be heard by project peers allows issues can be aired out before they start to fester and turn into a real problem. Fair dealing engenders trust, and Lean management cannot function without transparency and trust. Lean management requires meetings to be held, usually once a week, with all team members to review progress and discuss any issues.

Staff training is also important, both within the owner's organization and within the project team. In fact, project team members typically enter and leave the project throughout the duration of the project, and new members

need to be introduced to and trained in Lean management tools and procedures. Regular training — both introductory and refresher courses — need to be built into the project team culture.

Nurturing the project team's culture is extremely important. The single most important ingredient in a successful Lean project execution is a culture that reinforces and rewards behaviors that support Lean processes. Lean project implementation depends on the project team collectively learning from mistakes in real time, and defensive, non-transparent, anti-social forms of behavior from team members impede the development of a well-functioning team.

IMPLEMENTATION OUTCOMES

The first of the many projects UCSF completed using Lean design and construction techniques were new molecular biology lab buildings — one at the Mission Bay campus and one at the Parnassus campus. These began construction in 2008, and were completed in 2010. These were followed by the Benioff Children's Hospital at Mission Bay and Mission Hall, both completed in 2014. A number of complex laboratory remodeling projects were undertaken on the Parnassus campus at the same time, all using Lean techniques. Each project offers lessons that are worth reviewing.

UCSF's goal has been to pay costs that are competitive with similar building types and occupancy classifications, while achieving better performance and greater value. By using Lean techniques, the university has been able to achieve these goals, creating durable, attractive, and functional facilities that support the work of UCSF faculty and staff with minimal operating costs.

Using Lean techniques, construction costs have become more stable and dependable, and Lean projects have achieved greater building performance than traditional methods, as well as improved build quality.

CONCLUSIONS

The Lean design and construction principles UCSF has adopted have been successful in the university's capital program delivery processes. The benefits have included on-time delivery of complex laboratory and hospital projects, stable competitive costs, improved quality and building performance, and complete avoidance of claims. |

Notes

1. Pull planning is a method of advancing work when the next in line customer is ready to use it. A "request" from the customer signals that the work is needed and is "pulled" from the performer. In this way, work is released when the system is ready to use it.
2. Gregory Howell, "What is Lean Construction 1999," *Proceedings of the International Group for Lean Construction* 7, 1999.
3. Customer value is defined as the full range of desired performance characteristics and fitness-for-purpose achieved by the finished project in relation to cost.
4. Target value design is a disciplined management practice to be used throughout the phases of a project to assure that the facility meets the operational needs and values of the owner, is delivered within the allowable budget, and promotes innovation throughout the process to increase value and eliminate waste.
5. Inventory is a form of buffer, and all buffers cost something — but all processes need buffers to operate. Just-in-time delivery is a way of minimizing buffers and the costs they exact on processes, but eliminating buffers entirely is impossible.
6. In design-bid-build, the owner contracts with separate entities for the design and construction of a project. This is the traditional method for project delivery. As the name implies, it has three main sequential phases: design, bidding or tender, and construction.

7. Construction manager at-risk is a delivery method that requires the construction manager to commit to delivering the project at a guaranteed maximum price. "The construction manager acts as a consultant to the owner in the development and design phases (preconstruction services), and as a general contractor during construction." This kind of arrangement usually precludes a "low-bid" project. (Definition from Wikipedia.)
8. Best value is a process used for selecting an offer by evaluating and comparing factors in addition to cost or price, allowing for flexibility in trading off cost and non-cost evaluation factors in a way that provides the best value for the government's money.
9. In a cost-plus contract, a contractor is paid for all of its allowed expenses to a set limit, plus additional payment to allow for a profit, as opposed to a fixed-price contract, which pays the contractor a negotiated amount regardless of the expenses it incurs.

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Additional Resources

- Lean Construction Institute (<http://www.leanconstruction.org/>)
- Project Production Systems Laboratory, UC Berkeley (<http://p2sl.berkeley.edu/>)
- International Group for Lean Construction (<http://www.iglc.net/>)
- The Lean Construction Lighthouse (www.msu.edu/~tariq/Lean_Staff.html)
- Association of General Contractors Lean Construction Forum (<http://agcleanforum.org/>)
- Constructing Excellence (<http://www.constructingexcellence.org.uk/>)