

The Lean Project Delivery System: An Update

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Abstract

The Lean Project Delivery System emerged in 2000 from theoretical and practical investigations, and is in process of on-going development through experimentation in many parts of the world. In recent years, experiments have focused on the definition and design phase of projects, applying concepts and methods drawn from the Toyota Product Development System, most especially target costing and set based design. These have been adapted for use in the construction industry and integrated with computer modeling and relational forms of contract. Although by no means a finished work, the Lean Project Delivery System has developed sufficiently to warrant an updated description and presentation to industry and academia, incorporating processes and practices that have emerged since earlier publications.

Keywords: Lean project delivery, project business plan, project business plan validation, set based design, target cost

Introduction

“The hospital is a machine the design of which facilitates or impedes its fitness for use.” (Dave Chambers, Chief Architect, Sutter Health)³

The implications of Chambers’ statement are important and far reaching. One consequence is that the use of hospitals and other such facilities must be designed before the facility itself can be designed. Common practice in the process industries, it has now become evident that it should be extended to other types of facilities. Such considerations have become both more common and more urgent with the emergence of knowledge areas such as evidence based design, which specifies causal relationships between features of designed environments and both desired and undesired outcomes, and the increasing importance of designing for sustainability. Examples of evidence based design are shown in the following recommendations from Ulrich, et al., based on their 2004 evaluation of the published literature regarding healthcare facilities:

- *“Provide single-bed rooms in almost all situations. Adaptable-acuity single-bed rooms should be widely adopted. Single rooms have been shown to lower hospital induced... infections, reduce room transfers and associated medical errors, greatly lessen noise, improve patient confidentiality and privacy, facilitate social support*

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² Portions of this paper are drawn from Ballard, 2006 and Ballard, 2007.

³ Personal communication to the author

by families, improve staff communication to patients, and increase patients' overall satisfaction with health care.

- New hospitals should be much quieter to reduce stress and improve sleep and other outcomes.....
- Provide patients stress reducing views of nature and other positive distractions.....
- Improve ventilation through the use of improved filters, attention to appropriate pressurization, and special vigilance during construction.
- Improve lighting, especially access to natural lighting and full-spectrum lighting.
- Design ward layouts and nurses stations to reduce staff walking and fatigue, increase patient care time, and support staff activities such as medication supply, communication, charting and respite from stress."

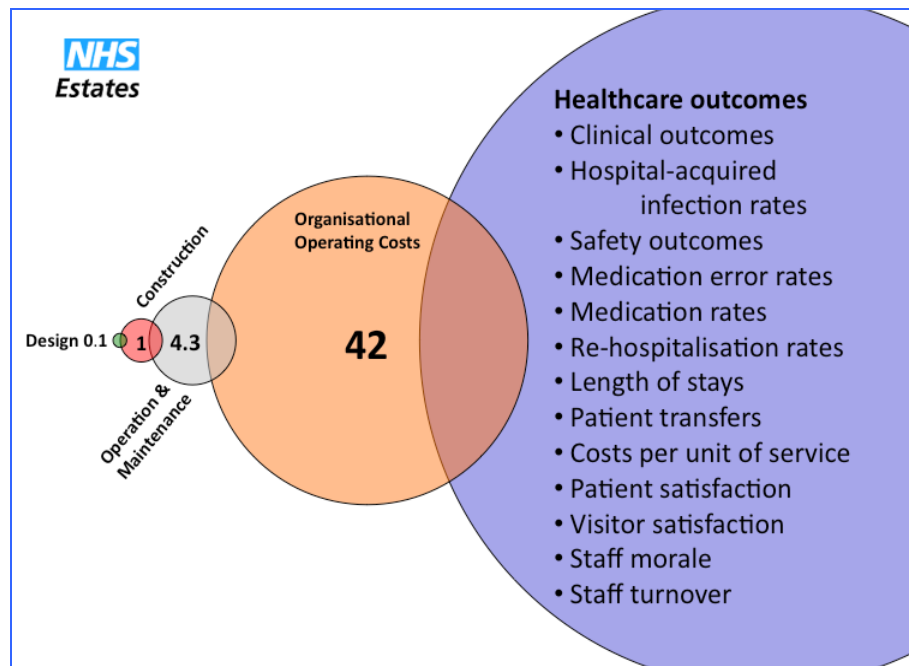


Figure 1: Relative Costs⁴

As shown in Figure 1, the relative costs of designing and constructing healthcare facilities pales in comparison to the costs of operations and maintenance. In turn, the business costs of using the facilities (e.g., salaries) far outweighs operations and maintenance costs. And finally, healthcare outcomes again far outweigh business costs. This shift of focus from first (capital) cost to whole life costs and outcomes is echoed in Saxon's 2005 publication *Be Valuable: A guide to creating value in the built environment*.

Given the perspectives and findings of Chambers, Ulrich, Saxon and Evans, it might seem that healthcare clients should be willing to pay more to get facilities better fit for use. However, the increasing cost of healthcare facilities and the profitability challenges of

⁴ The figure is based on Evans, et al., 1998. The list of healthcare benefits is from the UK's National Health Service. The operation, maintenance and business costs are for a 25 year period at net present value. Interested readers should also see Ive & Graham, 2006 for a critique of these ratios.

healthcare companies may make capital scarcity the vital statistic regardless of potential return on investment.

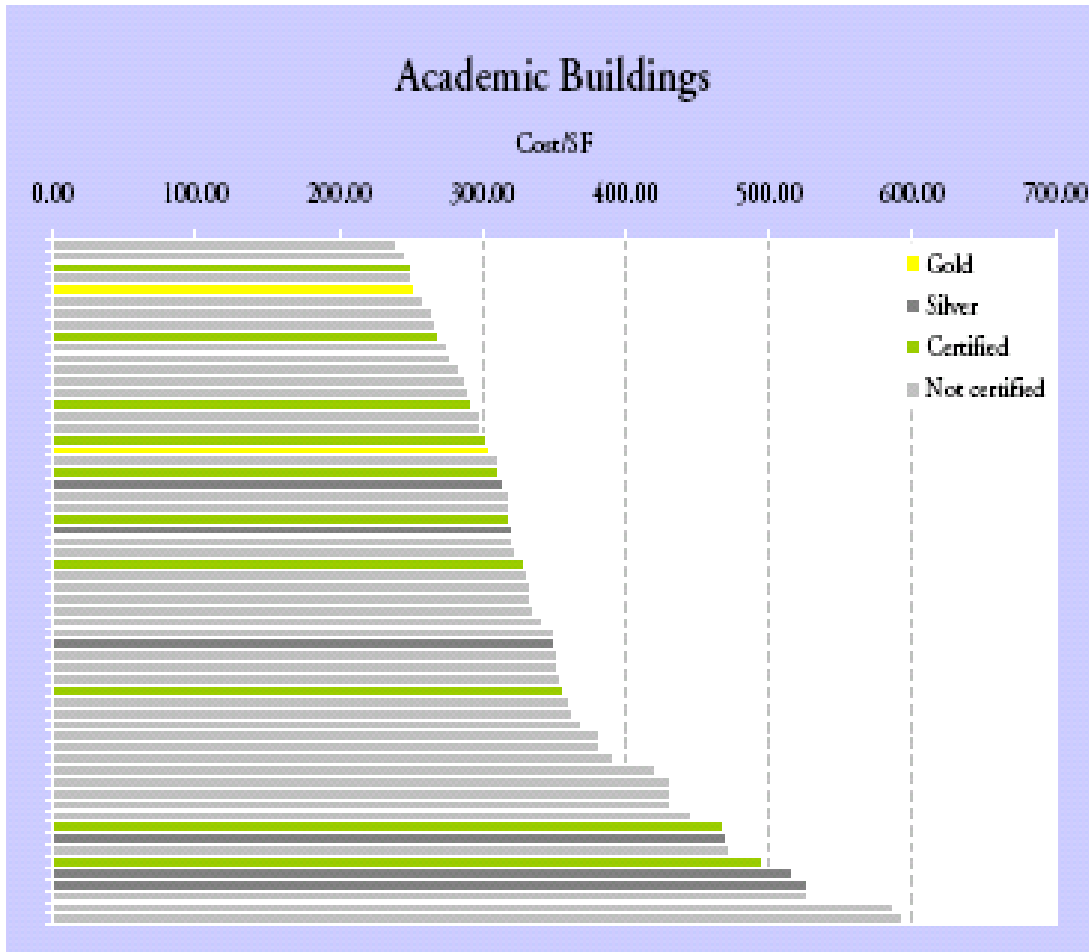


Figure 2: Must better buildings cost more? (Malthiessen & Morris, 2007)

Despite popular opinion, it is not so clear that better facilities cost more, or rather, that they must cost more. Figure 2 is from studies on the relative cost of green buildings by Mathiesson & Morris (2004 and 2007), both with the international cost consulting firm Davis Langdon. Design features that contribute to achieving sustainability objectives can be understood to be one aspect of ‘better buildings’. Incorporating evidence based design into healthcare facilities is similarly a way to design better healthcare buildings. The initial study of Mathiesson and Morris, published in 2004, found no statistically significant correlation between the cost of buildings in their extensive data base and the LEED rating (USGBC, 2008) of those buildings. This finding was confirmed in an update published in 2007.

Despite their findings, Malthiesson and Morris do not recommend disregarding first cost or simplistically subordinating first cost to whole life cost. They note that there is a wide difference in the cost of facilities otherwise similar in functionalities, capacities and LEED ratings. This suggests opportunity for eliminating waste, which is vitally important given the ever increasing cost of healthcare. If waste can be eliminated, better buildings can be designed and constructed for less than they would otherwise cost.

Our conclusion is to take on board the importance of lifting our eyes to see the complete life of a facility, while using the best thinking and methods to deliver more value for less cost. To that end, we propose the following hypothesis.

Hypothesis: Facilities *better fit for purpose* can be provided at *less cost*⁵ through rigorous project definition and through lean design and construction; i.e., through the lean project delivery system.

This paper follows the tradition of Lean Construction Institute white papers in proposing conceptual models that both reflect previous experimentation and encourage future experimentation.⁶ It attempts to support the above hypothesis by showing how the definition and design phases of projects can be managed to deliver value within constraints. The pace of experimentation is outrunning documentation. Consequently, the specific cases that are the basis of the conceptual models proposed will be reported in future papers. All cases have been carried out using an action research methodology, where the researcher actively participates in shaping, assessing and revising field tests of management practices thought to be improvements on previous practice (see description of action research at Project Production Systems Laboratory website: p2sl.berkeley.edu).

The Lean Project Delivery System - Project Definition

Figure 3 is a schema of the Lean Project Delivery System, a prescriptive model for managing projects, in which Project Definition is represented as a process of aligning Ends, Means and Constraints. Alignment is achieved through a conversation that starts with the customer stating:

- what they want to accomplish (have a place to live, capture a market for the goods they produce, provide a school so their children can be educated)
- the constraints (location, cost, time) on the means for achieving their ends

This does not appear to be common practice. In the author's experience, clients often start by dictating means rather than revealing purpose, and rarely reveal what they are able and willing to spend to get the means for realizing their purposes.

Architects, engineers and constructors (AEC professionals) may be understood by some to have the job of providing the means requested by customers, who may or may not reveal their purposes or values. In this tradition, the AEC professional has no role in specification of customer purpose and value.

At first glance, this appears to be a reasonable practice. Apart from illegal or unethical objectives, the AEC professional has nothing directly to do with customer purpose. The same holds true for the constraints on means for fulfilling customer purpose. However, there can be an indirect impact on purpose and constraints. For example, suppose you want to buy a flat in a ritzy area of town. That desire might change once you understand the cost. Alternatively, if you better understood what was available, you might be willing to spend a bit more than you originally planned.

⁵ "Cost" here signifies all the costs shown in Figure 1 (Relative Costs).

⁶ For Lean Construction Institute white papers, see www.leanconstruction.org. Ballard (2000) is especially relevant as the white paper on the Lean Project Delivery System.

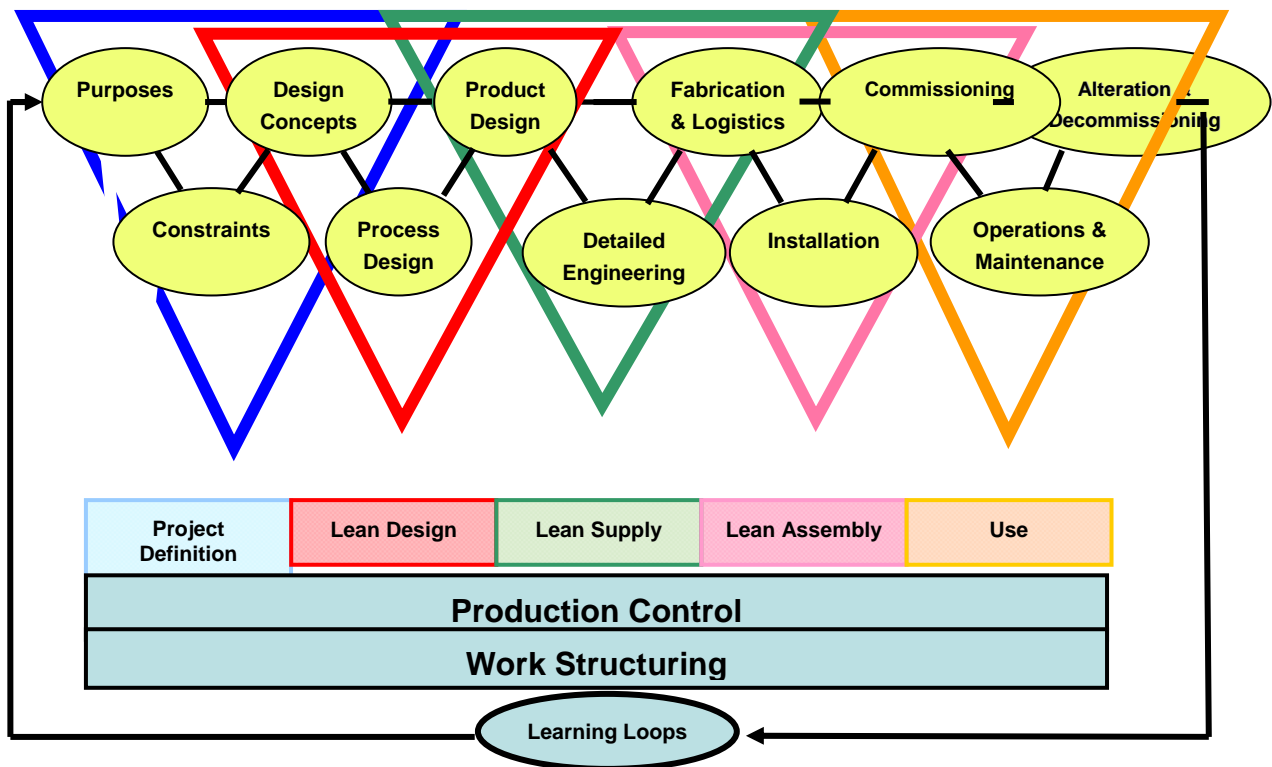


Figure 3: Lean Project Delivery System (Ballard, 2000 and 2006)

In the Lean Project Delivery System, it is assumed that the job of the project delivery team is not only to provide what the customer wants, but to first help the customer decide what they want. Consequently, it is necessary to understand customer purpose and constraints, expose the customer to alternative means for accomplishing their purposes beyond those they have previously considered, and to help customers understand the consequences of their desires. This process inevitably changes all the variables: ends, means and constraints.

We now look more closely at Project Definition, using Figure 4. This conversation may start with the Customer voicing what they want—a bridge across the river, a 2 bedroom flat near downtown, etc. But what’s needed is to work back to customer purpose—what are they trying to accomplish? What do they intend to do with the flat, bridge, factory? If purpose is understood, then it is possible to determine what features of the product are valuable; i.e., what features are means for realizing that purpose. But to incorporate those values into the product, it is necessary to translate from the voice of the customer into the voice of the engineer. That involves moving from “I want to be able to hear a pin dropped on stage from any seat in the balcony” to specification in decibels of the sound at specific locations in the facility. Both of these linkages are difficult and critical; linking purposes and values, and linking values and engineering specifications/design criteria.

That is one set of motions, entirely within Ends. A second motion occurs within Means. If it is true that “A hospital is a machine....” , and if this applies to at least some types of constructed products, then for those product types, it is necessary to first design how the product will be used before designing the product (facility) itself. In some cases, prior analysis of facility operations reveals ways to improve an existing facility and avoid the cost and time of new building.

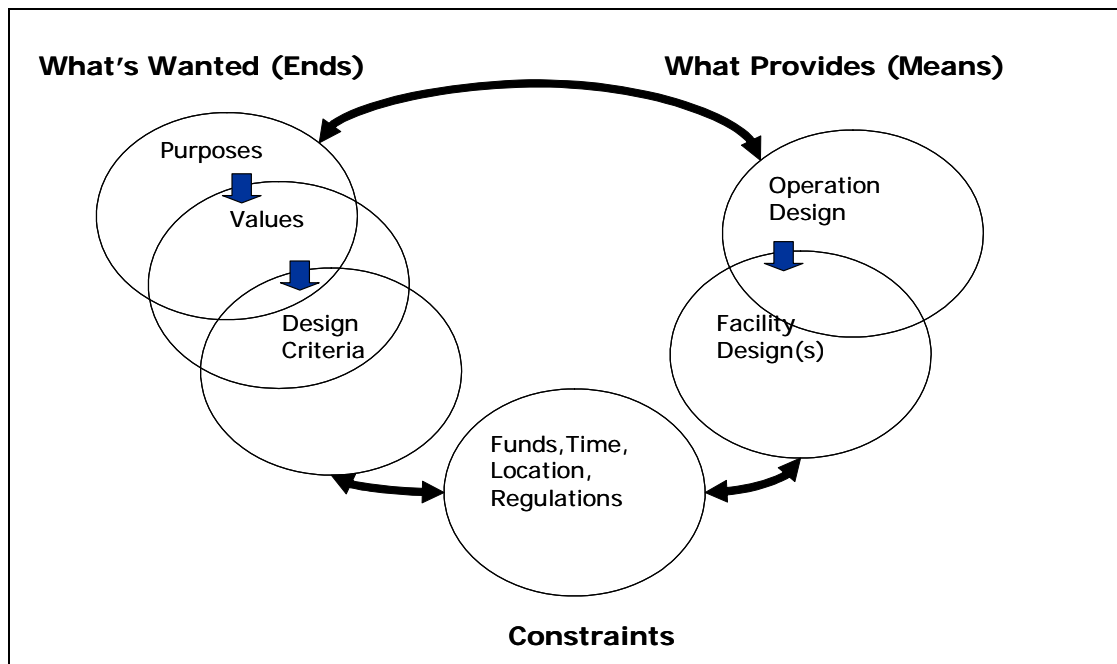


Figure 4: Project Definition Process

Finally, there is the conversation between Ends, Means, and Constraints. As Ends are more clearly defined and translated into Design Criteria (specifications), and as the design-for-use of the facility emerges, constraints are also better defined. What are you able and willing to spend? When do you need to have the facility for your use? What are the implications of alternative locations for geotechnical, meteorological, cultural and regulatory conditions? Cultural criteria link projects and buildings to the communities in which they are located, and to the values and interests of that set of stakeholders.

It is hopefully apparent that Ends, Means, and Constraints are mutually determined and so become progressively clearer through conversation. But does this ‘conversation’ between ends, means and constraints apply to all types of construction projects and to all types of clients? Consider the client types included in Table 1.

The Developer is a construction client who is creating something to sell to others. The relevant financial considerations are maximum available funds and minimum acceptable return on investment. The appropriate action is to use target costing, which starts with the client specifying the amount of money they are able and willing to spend to get what they want. An example of this client type is a property developer.

The Producer differs in his purpose, which is to produce a means of production for his own use. Examples are manufacturers, healthcare companies, and educational institutions.

The Shopper’s purpose is to acquire a commodity; i.e., a pre-designed, standard product, with invariant quality. The financial consideration is ability to afford and the appropriate action is to buy at the lowest price. Some professional services firms appear to fit this category when they build buildings for their own use, thinking that facility design has little impact on its fitness for their use.

Finally there is the Art Collector, so called because their purpose is to create something the properties of which cannot be predefined. Here, design truly drives cost, rather than the opposite, as money may be raised in response to the attractiveness of the design.

Municipalities and arts foundations are examples of this client type. But even in this case, cost becomes a constraint on design at some point in the project delivery process.

Table 1: Client Types

	Purpose	Finance	Action	Example	Comments
Developer	Create something to sell to others	Maximum available funds or minimum acceptable ROI	Target cost	Property developer	
Producer	Create means for producing products or services	Maximum available funds or minimum acceptable ROI	Target cost	Oil refiner, healthcare company, university	
Shopper	Acquire commodities	Ability to afford	Buy at lowest price	Law firm, insurance company	But note: If facilities are not commodities and can impact use benefits through different designs, then Shoppers are actually Producers, and buying at lowest price is not likely to deliver greatest value.
Art Collector	Create something without predefinable properties	Within initially indeterminate limits, funds can be acquired based on the attractiveness of the design.	Design, then estimate cost, then acquire funds.	Municipal library, performing arts theater	At some point, maximum available funds will constrain the design. That point may occur earlier or later in the design process.

The only type of client for which the ends/means/constraints conversation would seem to be completely inappropriate is the Shopper, precisely because the product design is already produced. And it is certainly true that some types of previously custom-designed construction products can and should be ‘commoditized’; i.e., treated rather as a product of repetitive manufacturing than as a construction product. However, it is still desirable to tweak standard designs to increase customer value (fitness for purpose) where possible, even when those purposes are widely shared, as is the case in housing.

Perhaps it is safe to say that the ends/means/constraints conversation is needed whenever a product is designed, if the product is to be optimally fit for the intended customer use within customer constraints. As noted, constraints eventually limit design even for the Art Collector. However, given the peculiarities of that client type, the subsequent discussion is most directly applicable to the Developer and the Producer.

Business Planning and Plan Validation

As shown in Figure 5, in the Lean Project Delivery System, project definition starts with business planning, proceeds to business plan validation if the initial plan appears to be feasible, and ends with a decision by the client to fund or not fund a project. If the project is not funded, the companies participating in business plan validation are paid for

their services and the project is killed. If the project goes forward, target values and constraints are set, then design is launched and steered toward those targets. If the project team is unable to develop a design that delivers value within constraints, business planning and validation are reengaged. Major problems with permits or licenses may also require return to business planning. Finally, we must eventually build to the targets as well, but that is outside the scope of this paper, which stops at the end of design.

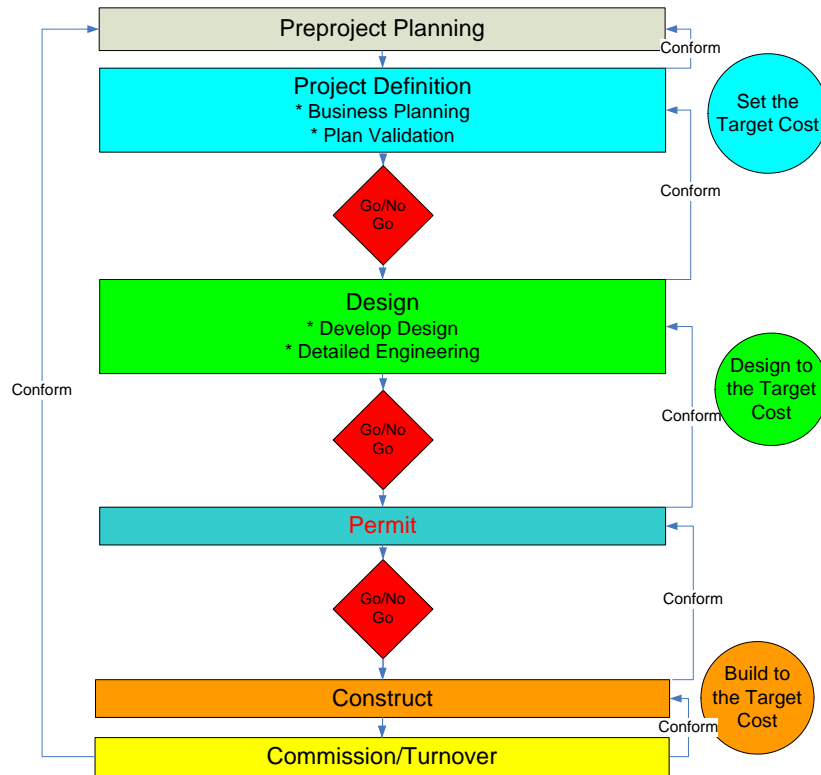


Figure 5: Project Phases and Target Costing⁷

As previously mentioned, the AEC professional cannot replace the customer in deciding on purpose and constraints. AEC professionals are not expected to contribute to demand forecasting, evaluation of alternative options for achieving strategic objectives, or the specification of constraints (cost, time, location, regulations) on successful project delivery. The practical implication of this fact is that the project business plan is first developed by the client, perhaps with assistance from some specialized consultants, and then key members of the project delivery team are engaged to help validate and improve that business plan.

Business Planning

Prior to forming the project delivery team, the client develops the initial project business plan in answer to the question: “If we could have facilities X (means) within applicable constraints, and if use of facilities X would enable us to achieve objectives Y (ends), would we do it?”. Applicable constraints typically include cost and time, so the client must

⁷ The target costing process diagrams in this paper are based on diagrams produced for Sutter Health by the Project Production Systems Laboratory, University of California, Berkeley.

specify what money and time they are prepared to spend in order to achieve their ends. This is quite different from normal practice. Clients usually resist revealing their bank account lest it be emptied and spent without regard to the value they receive.

Target costing is a term that has been used with a variety of meanings. In this paper, it is defined in relation to allowable cost and expected cost. What a client is able and willing to spend to get what they need to accomplish their purposes or ends is the allowable cost for a project. The determinants of allowable cost always include capital availability and ability to repay/recover. These are minimum requirements. Some clients also include stretch goals in their initial statement of Allowable Cost, in an effort to improve profitability or some other performance metric. The allowable cost may be adjusted to match expected cost, or reduce the gap between allowable and expected, so long as the minimum requirements are met; namely, fitness for purpose, capital availability and ability to repay/recover. Incorporating targets in the allowable cost is more common for clients working with preferred providers over a series of projects, and is standard practice in product development (Cooper & Slagmulder, 1997 and 1998). The first publication of which this author is aware on the application of this product development practice in the construction industry was Nicolini et al., 2000, and the first successful application was reported in Ballard & Reiser, 2004. Cost planning in the quantity surveyor tradition has strong similarities and shares the key distinction; namely, designing to cost versus costing a design (Langston, 2002).

Allowable Cost \geq Expected Cost \geq Target Cost (Equation 1)

The Expected Cost is the forecast or estimated cost of the project at current best practice; e.g., based on benchmarking against similar facilities or some type of cost model. If the expected cost is greater than the allowable cost, the project does not meet the client's business case and the project should either be abandoned or the business case revised. A client might choose to proceed without revising the business case, but should do so recognizing the risk of cost overrun.

The Target Cost is what the team commits to deliver, sometimes contractually and sometimes 'only' morally, and is typically set below the expected cost in order to spur innovation beyond current best practice. Institutional clients often are less concerned to recover funds once budgeted, and so tend to set targets in terms of value-adding scope to be delivered for a given cost.

Business Planning

1. Assess the business case (demand, revenues), taking into account the cost to own and use the facility (business operations, facility operations, facility maintenance, adaptability, durability) as well as the cost to acquire it.
2. Determine minimum acceptable ROI or maximum available funds—set the allowable cost for the facility: what the client is able and willing to pay for what they think they want.
3. Answer the question: If we had a facility with which we could achieve our specific purposes, and if we could have that facility within our constraints of cost, location and time, would we do it?
4. If the answer is positive, and if project delivery is not considered risky, fund the project. If the answer is positive and project delivery is considered risky, fund a business plan validation study to answer the question: Can we have the facility we have in mind, will it enable us to achieve our purposes, and can we acquire it within our constraints?

Business Plan Validation

If the business plan is considered achievable, the client may choose to fund the project at the expected cost, previously aligned with their allowable cost, and launch the project. This decision is based on the client's assessment of risk, and on the client's desire to outperform previous benchmarks. For business plans considered risky or for projects with considerable stretch goals embedded in target values or costs, the client forms a team of AEC professionals to validate the business plan. The client is an active member, and does not simply commission the production of a report. Team members will deliver the project if funded. The Business Plan Validation team answers the question: "Can the client have facilities X within applicable constraints, and will use of facilities X enable them to achieve objectives Y?" The initial business plan may change during the team's deliberations, which is completed if and when ends, means and constraints are aligned, or when it becomes apparent that they cannot be aligned. At this point, the team reports its findings and the client decides if to fund the project. If funded, the project team initiates design.

Business Plan Validation

- Select key members of the team that will deliver the project if judged feasible.
- Determine and rank stakeholder values.
- Explore how the facility will perform in use through process modeling and simulation.
- Describe the facility that will deliver the values.
- Determine the expected cost if the facility were provided at current best practice.
- If expected cost exceeds available funds or violates ROI, attack the gap with innovations in product/process design, restructure commercial relationships, etc.
- If expected cost still exceeds available funds or violates ROI, adjust scope by sacrificing lesser ranking values.
- If the scope and values that support the business case can be provided within financial and other constraints, fund the project. Otherwise, change the business plan or abandon the project.

Both business planning and plan validation benefit from following the advice of Emmitt and his fellow authors (Emmitt, et al., 2004) to first Vision, then test that vision against Reality.

Three hospital projects in the San Francisco area have just completed business plan validation. Each validated their project business plans; meaning that they studied the situation, understood what their clients were trying to do, explored design alternatives, evaluating them against client and stakeholder values, and concluded that the hospitals could be designed and constructed within the available time and money, with an acceptable level of risk. Case studies on their plan validation processes are being developed and will be published in due course.

If, in the course of the project, the business plan is brought into question or changed, the plan validation process starts again. Usually these changes will be minor, but major shifts in strategies, market conditions, technologies or regulations could require more substantial investment in re-validation. The client will need to decide if it is preferable to continue or divert, depending on the phase of project delivery in which the change in business plan occurs, and the expected costs and benefits of making or not making the change.

Lean Project Delivery System-Design

The first step in the design phase of the Lean Project Delivery System is target setting. The second and third steps, design development and detailed engineering, are steered toward those targets.

Target Costing

Target costing is a method for shaping product and process design for delivery of customer value within constraints. This method can be understood as one application of a production-oriented business management philosophy that self-imposes necessity as a driver of continuous improvement and innovation—what Jeffrey Liker describes in his 2004 book *The Toyota Way*. Perhaps the most famous articulation of this philosophy was Taiichi Ohno’s recommendation to ‘lower the river to reveal the rocks’; i.e., to periodically reduce the buffers of inventory, capacity, time and money that absorb waste-causing variation in order to stress the production system and reveal where it needs improvement (Ohno, 1988).

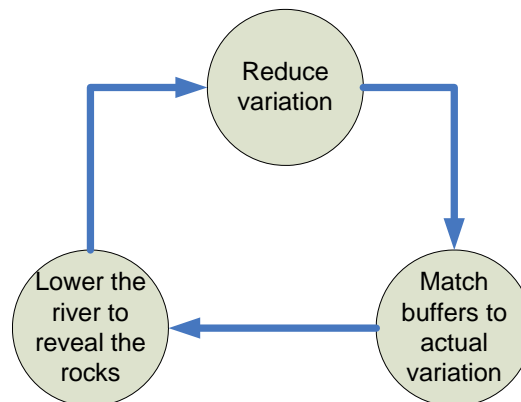


Figure 6: Improvement Cycle

We learn and improve performance from experiments and breakdowns. Experiments are intended deviations from standard. Breakdowns are unintended deviations from standard. Process improvement is achieved by reducing variation through experiments and through acting on the root causes of breakdowns.

The job of buffers is to absorb variation. Once variation is reduced, the next step is to match buffers to actual variation (Figure 6). There appears to be considerable opportunity in the construction industry simply starting from this point, as buffers of inventory, capacity, time and money (financial contingency) frequently exceed what is needed when projects are managed with even a minimum of lean concepts and methods. This phenomenon is in large part a function of the way traditional contracts fail to align incentives, thus encouraging local optimization. In the following, we abstract away from contractual structures and relationships, and focus on what can be done to better manage production systems in general.

Matching buffers to variation involves first selecting the right type of buffer--inventory, capacity, time or contingency⁸ (see Hopp and Spearman, 2000), then locating the buffer appropriately in the process, and finally sizing the buffer.

Reducing variation and matching buffers to the remaining variation stabilizes a production system. The next step is to deliberately de-stabilize it by reducing buffers below what's needed to absorb existing variation. This is an experiment, and should be undertaken with care, lest the revealed rocks put a hole in our commercial boat!

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|---|---|
| <ul style="list-style-type: none">• Great high-speed handling/stability• Fast and smooth ride• Super quiet• Elegant styling• Warm• Great stability at high speed | <ul style="list-style-type: none">• A pleasant ride• Low fuel consumption• Light weight• Great aerodynamics• Functional interior• Low aerodynamic friction |
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Figure 7: Suzuki's YETs (Liker, 2004)

The very neat example shown in Figure 7 comes from Jeffrey Liker's *Toyota Way*. The chief engineer for development of Toyota's Lexus was Suzuki. His method of challenging the product development team was to take away traditional design solutions by demanding previously incompatible product features. For example, noise reduction had previously been achieved principally through using mass to absorb vibration. By demanding that the Lexus be both "super quiet" yet "light weight", Suzuki forced the power train engineers to attack the source of noise, engine vibration. This led to an engine built to much tighter tolerances than had previously been thought possible, and to a light weight yet quiet automobile.

We can reduce each type of buffer (inventory, time, capacity, contingency) in order to 'lower the river to reveal the rocks'. For material inventories, the classic example is Ohno pushing machines together so there was no space for work-in-process inventory, directing attention and effort to balancing the cycle times of connected machines rather than concealing that unevenness with inventories that allowed machines to continue producing. That can be done in construction by limiting laydown space on site. Perhaps there is a similar physical way to limit the storage space for information, the form inventory takes in design, but at least transfer batches of design information can be limited in size by rule. Suzuki's YETs is an example of reducing the inventory of traditional engineering solutions. We can reduce the durations of project phases or operations, thereby directing attention and energy to improving the predictability of work releases from one specialist to the next. We can set productivity (capacity) targets the achievement of which require reductions in time workers spend waiting, searching and reworking; as well as encouraging innovations in design buildability, technologies, and work methods. We can reduce financial contingencies in our budgets to provoke innovation in system design and in project management practices so that previously required contingencies are no longer required.

There are two primary options for setting targets: a) Set the target cost lower than the budget that assumed current best practice and was aligned with the business plan, or b)

⁸ It might be argued that funds are not a fourth type of buffer, but rather means for acquiring inventory, capacity or time. In any case, managing buffers of financial contingency is critical to the successful performance of project production systems.

Set target scope greater than what could be delivered with current best practice for the budget. In other words, target the delivery of more value for a given cost, as opposed to the delivery of a minimum value for less cost. Clients decide between these two options depending on their circumstances.

Returning now to the Lean Project Delivery System, we have validated the business plan, secured authorization and funding for the project and set target values and constraints. Next comes design development.

Design Development

In Lean Project Delivery, we distinguish between design development and detailed engineering.

The major steps involved in Design Development are:

- Form target costing teams by system and allocate the target cost to each team
- Hold a kickoff workshop
- Launch meeting schedule
- Use a set based approach, evaluating sets against target values
- Provide cost and constructability guidelines for design; e.g., product/process standardization
- Promote collaboration; e.g., have designers get cost input before drawing
- Do rapid estimating; hold frequent budget alignment sessions
- Use value engineering proactively, not after the fact
- Hold periodic design reviews with permitting agencies

Set based design was identified as a key methodology in Toyota's Product Development System in Ward et al.'s 1995 Sloan Management Review article. The basic idea is to apply all relevant criteria in producing, evaluating and choosing from design alternatives from the outset of design, rather than introducing new criteria as new players come onto the team. This implies that all key players, upstream and down, architects, engineers, general contractors, specialty contractors, regulatory agencies, and perhaps even suppliers become members of the design team.

All members of this expanded design team have to relearn how to do their jobs in this new arrangement. Experiments to date are encouraging, but sometimes reveal huge cultural barriers and the seductive power of habit. As long as the industry is in a primary experimentation mode, projects will benefit from 'hot house' conditions such as co-location, which may become less important as new practices and attitudes become standard operating procedure. However, it should be noted that Toyota introduced co-location, in the form of the obeya (big room), into its product development process with the Prius. On more complex and challenging projects, hothouse conditions may become standard practice. The technical challenges of achieving sustainability objectives may well require co-location and other social innovations that facilitate collaboration.

Detailed Engineering

The major steps involved in detailed engineering are:

- Identify the uses of design: permitting, bidding, purchasing, providing submittals, specifying facility systems, producing fabrication and installation instructions, commissioning, operating, maintaining, altering and decommissioning
- Kickoff workshop
- Pre-meetings with permitting agencies
- Design specialists and users jointly produce needed information for each use; preferably by detailing and extraction of multiple documents from an integrated model

By way of example, in response to an industry-wide lean construction initiative, the state of California recently passed a law authorizing the state permitting agency for healthcare facilities to do phased permitting. As a result, agency personnel are now involved early on projects to make sure no resources are expended on design alternatives that will not pass review, and to structure agreements about what specific documents will be required when. Already this has reduced the time added to a pilot project from 18 months to less than 6, and a cross-industry team, including the permitting agency, is working to reduce that even further—with 10 pilot projects underway throughout the state.

Permitting is but one of many uses for which design must be developed. Shop drawings (fabrication and installation instructions) are now being produced collaboratively by designers and specialty contractors/fabricators, as opposed to the traditional method in which submission and review were all too often followed by rework to fix deficiencies. On Sutter Health's Camino Medical Center project, the specialty contractors used the obeya (big room) concept to collaboratively detail the mechanical-electrical-plumbing work. The \$95 million project was completed with 40 confirming RFIs, without filling a single 55 gallon drum with sheet metal scrap, and with a substantial underrun of the labor budgets for on site installation (Khazode et al., 2006). It should be said that 3D modeling makes this collaboration much more feasible and effective.

The key here is to think of fabricators, permitting agencies, facility maintenance workers, etc. as customers of the design process, and to involve these customers as active participants in the design process.

Note also that at the beginning of each phase of the project, Ends, Means and Constraints are reviewed in an effort to maintain alignment. If these are not aligned, then the project cannot be successful.

Shawano Clinic

Let's look at one project, Shawano Clinic, to see the impact of lean project delivery. On this project, the target cost was embedded in the client's allowable cost. Figure 8 shows the project cost budget and how the expected cost changed over time in relation to the target cost. Ultimately the target cost was achieved, along with a return to the client of unused contingency and funding of client changes without additions to the budget.

Expressed in percentage terms, the target cost (construction budget) was set 3.6% below the current best practice benchmark, the actual cost was 14.6% below target, and 17.6% below the benchmark. Most of the released funds were used to provide value-adding scope, especially for imaging capability, with the remainder returned to the client. In addition, the project was completed 3.5 months ahead of schedule, generating 70 additional days of clinic revenue for the owner, amounting to nearly \$1 million.

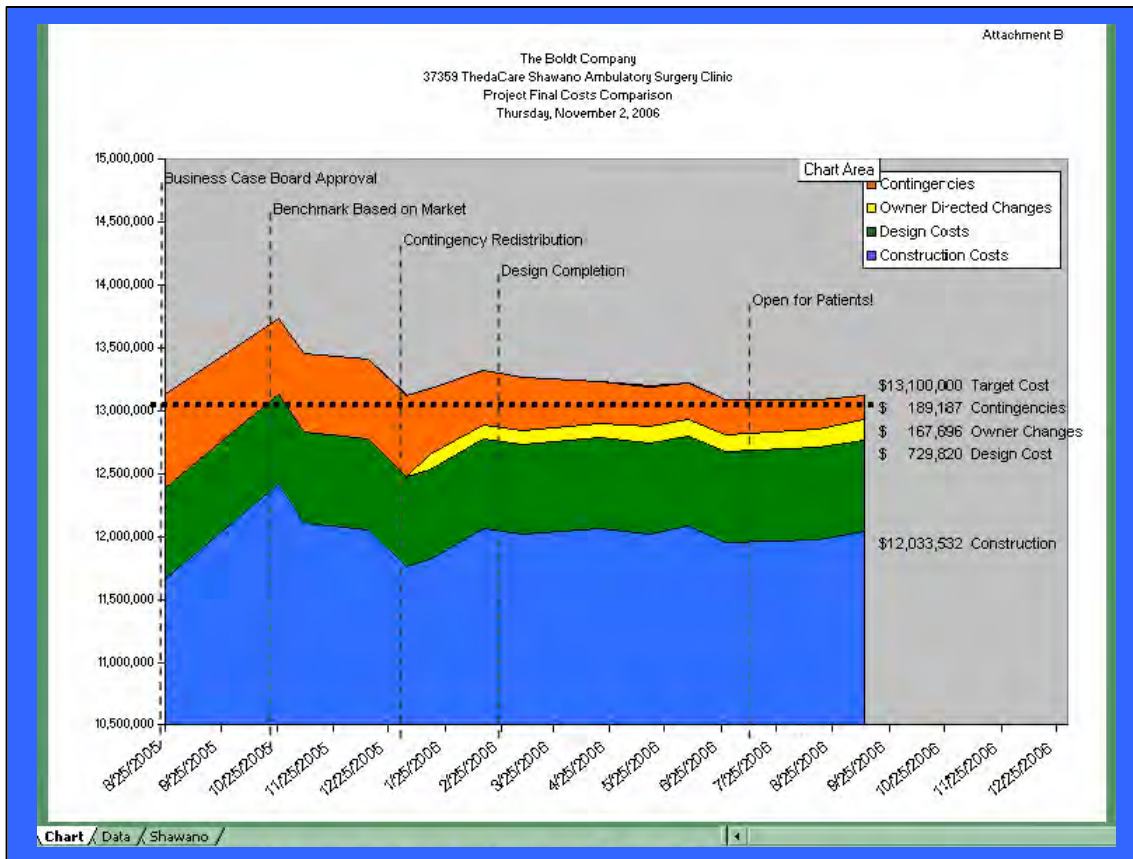


Figure 8: Shawano Clinic

Conclusion

This conclusion consists of a summary of what's been argued and presented, and a call for future research and experimentation.

Summary

An update has been provided on the project definition and design phases of the Lean Project Delivery System. A primary starting point for the approach is the claim that project teams are responsible for helping customers decide what they want, not just for doing what they are told. Key steps in the process are:

- Clients specify what they are able and willing to spend to get what they want
- How the facility will be used is designed before designing the facility
- Design criteria are developed from values and values from purposes
- Clients engage key members of the project delivery team to help validate and improve project business plans
- Target values and constraints are set as stretch goals to spur innovation
- Design is steered toward targets using a set based approach in which alternatives are evaluated from the outset against all design criteria and constraints and decisions are made at the last responsible moment

- Users and designers collaboratively produce instructions for use of the design (purchasing, permitting, fabrication, installation, commissioning), preferably from a 'single' model that enables detection of dimensional clashes and code violations.

Future Research

The approach to project delivery described here is based on industry experiments, some completed, some still underway. The Terminal 5 Project at Heathrow Airport employed some aspects of the practices described here, but applied lean project delivery methods more in its contractual structure and construction execution than in definition and design. Completed projects that more completely implemented the approach described here include two from Sutter Health; namely, the Acute Rehabilitation Project (ARC) for Sutter Roseville Medical Center and the Fairfield Medical Office Building for Sutter Fairfield⁹. ARC reversed a long string of over budget projects, very nearly achieving an aggressive target cost in conditions of rapid cost escalation. The Fairfield story is very similar to Shawano's, delivering greater value than in the original scope and doing so at a target cost well below industry standard. The project target cost (\$18.9 million) was set 14.1% below the benchmark (\$22.0 million). The actual cost (\$17.9 million) for the original scope underran the target by 5.3% and underran the benchmark by 18.6%.

The lean approach to project delivery is by its very nature unfinished. Improvement is possible in every aspect: processes, methods, tools. Specific to what has been presented here, research is needed on capital budgeting, contracting, risk management and contingency, cost modeling, and cultural change.

The practice of target costing has thus far proven very successful in both healthcare and education, but more thorough documentation of that success is needed, along with further development of the various tools and methods employed. Capital budgeting specifically offers several opportunities:

- Better understand current practice in different sectors. To what extent are allowable costs methodically developed? To what extent can they be? Exactly how are capital availability and potential returns modelled in the calculation of allowable cost? How does or might this practice differ in different contractual circumstances, with different allocations of incentives and risks?
- What are the non-technical obstacles to better capital budgeting in different sectors? For example, some report that healthcare management is often unable to exploit the potential in facility designs. If true, this is an obstacle to investing in life cycle benefits. How have PFI and PPP changed this dynamic?
- Another such obstacle may be the inability for money to move across internal organizational boundaries between those responsible for capital costs and those responsible for business use of facilities. These obstacles must be better understood in order to be attacked and removed.
- The ultimate objective for capital budgeting might be to develop and link cost models for capital cost and business use, to use those models to determine allowable and expected cost based on initial understanding of design options and potential benefits, then to provide those linked cost models to the project delivery

⁹ Case studies on Shawano Clinic and the Fairfield MOB projects are in preparation by the author. Technical reports are also being prepared on the definition and design phases of a major hospital project in San Francisco that is using the target costing methodology described in this paper.

team so they can recalculate allowable cost based on estimated future net returns from business use of the facilities being designed. This self-generation of capital budget during the course of a project would obviously be limited by the availability of capital, which also needs more thorough study and understanding, but could provide the project team, client included, with the means to steer a project in flight toward greater delivery of value.

Contracts are needed that align the interests of project team members in pursuit of the lean ideal; i.e., to deliver the project while generating value and reducing waste. This type of contract has been called “relational”. A number of projects have been successfully executed using relational forms of contract, one example of which is Sutter Health’s Integrated Form of Agreement, developed by Will Lichtig of McDonough, Holland and Allen, their outside counsel (Lichtig, 2007). Although these projects have been reported and discussed in industry meetings, case studies have not been published that explicitly identify and evaluate changes in a way that facilitates further development.

The explicit management of risk has not been described in this paper, but is a critical part of successful project delivery, and should be incorporated into future experiments. Of special importance is learning how to select, locate and size contingencies to buffer against risk. As mentioned in this paper, construction projects have tended to include buffers in excess of what is needed to absorb variation. With the introduction of relational contracts, the motive to local optimization will be eliminated, and all types of buffers, including financial contingencies, should be able to be reduced without additional risk to successful project execution. Experiments testing this hypothesis are needed.

Research is also needed on various aspects of cost modeling. The first issue is the feasibility of developing cost models directly from the voice of the customer, in the project definition phase, as opposed to developing cost from design. This has been done for many years by Haahtela in Finland using an underlying ‘building information model’ (Pennanen, 2004 and 2008). A different approach has been taken by Scott Morton of the Boldt Companies (Morton, 2008). Morton’s is a benchmarking approach that blends ratings of facilities against multiple criteria into a single index number that can be correlated with historical unit costs. The research questions or topics include differentiating these methods one from another and from cost modeling based on conceptual design options, and also the applicability of this method to types of projects or clients. Can Haahtela’s cost model, based on an underlying building information model informed by customer choices, be successfully applied to a variety of facility types in different geographic markets? The same questions apply to Boldt’s ‘quarterback rating’. A second research topic in cost modelling is extending cost models to the 5th dimension, incorporating cost. The author is collaborating on research with Pennanen, Morton and others on these issues, but additional researchers and research are needed and welcome.

The Lean Project Delivery System requires cultural change. New forms of contract and unaccustomed roles and responsibilities require new ways of behaving and thinking. Descriptive research is needed on the experiments currently underway to enable better understanding what works and what does not, which in turn is the basis for defining and executing experiments on future projects.

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The Lean Project Delivery System is not a mere creature of the imagination, but rather an emerging practice fed by multiple streams of experimentation. The individuals and companies conducting these experiments are too numerous to name, but their contributions should be acknowledged. The author's own thinking has been developed in collaboration with members of the International Group for Lean Construction, the Lean Construction Institute and its international affiliates, and the Project Production Systems Laboratory at the University of California, Berkeley.

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