TARGET VALUE DESIGN
Introduction, Framework, and Current Benchmark

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Executive Summary

Target Value Design (TVD), referring to the application of Target Costing (TC) to the delivery of projects in the Architecture-Engineering-Construction (AEC) industry, radically differs from what has become the traditional way of designing and making products. Rather than treating cost as an outcome of wasteful design-estimate-rework cycles, TVD is a method that makes customer constraints (on cost, time, location, and others) drivers for design in pursuit of value delivery.

This document introduces TVD by retracing its roots and describing why owners and, in fact, all project participants can benefit from using TVD. It presents the components of a TVD framework, detailing how this lean method applies in practice to the delivery of a capital asset such as buildings, and then offers the current benchmark to those who wish to get started using TVD or assess their current practice. A glossary at the end recaps the terms introduced in the text.

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1. What is Target Value Design?

1.1 Target Value Design's Origin in Target Costing

Target Value Design (TVD)[1] is a method for setting project targets and steering design and construction toward them. The process was adapted from the **target costing (TC)** used by consumer[2] and industrial product manufacturers to manage product profitability (Cooper & Slagmulder 1997, 1999). After defining the functionalities of a new product and conducting market studies, the manufacturer estimates the revenues they will receive from sales and subtracts the profit they consider acceptable (the so-called target profit): the remainder is the target cost—the maximum amount of money they can spend on designing, manufacturing, servicing, and disposing of the product and still make their target profit.

Because of two major differences between product development used for manufacturing vs. construction, namely (1) the customer's role in the process and (2) the nature of the product, the practice of target costing used in manufacturing requires adaptation to suit the specifics of the architecture-engineering-construction (AEC) industry (Ballard 2012). The construction customer initiates and structures project delivery for a product that is unique, produced specifically to suit their goals, and constructed and used in a specific location; in contrast, a manufacturer develops a product that is to appeal to a range of customers, can be made more-or-less anywhere using repetitive manufacturing, and is then transported to its point of use. The unique nature of the product poses challenges both to accurate estimating of costs and benefits from use of the asset to be constructed (asset worth), and to accurate estimating of cost to procure.

Two opposing objectives drive construction project budgets. Budgets are driven higher by the objective of providing sufficient funds to achieve project goals (program and scope) in conditions of uncertainty, and driven lower by the objective of spending no more than necessary to accomplish those goals. This poses two risks, in tension with each one another: (1) running out of money and (2) leaving money on the table, as may happen when rejecting scope or value early and then identifying savings later when the value can't be recovered.

1 Words in **bold** are defined in the glossary at the end of this document.

2 The term "consumer" is used interchangeably with "customer," "buyer," "client," or "owner."

Finding the balance point between them is a challenge not always met—some might say "infrequently met." Projects can and do fail both ways.

TVD helps construction project teams strike this balance by structuring their pursuit of these two objectives using two different financial elements, rather than a single one. On the one hand, the objective of providing sufficient funds to achieve project goals is to be met by specifying as the project budget the most a client is willing and able to spend (e.g., per their business plan) to achieve the goals of the project. This **allowable cost (AC)** is based on the worth to the client of the asset to be constructed and is the most conservative basis for budget setting consistent with project economic viability. On the other hand, the objective of spending no more than necessary is commonly met through an incentive of shared savings or profit at risk with those involved in project delivery so as to spur innovation in both product and process design, developed concurrently, and hence reduce the actual cost. For a TVD project team to achieve success, the organizational structure and commercial terms must allow this balancing act to take place.

1.2 Chronology of Use in the AEC Industry of Target Costing and Target Value Design

The practice of defining a target cost and then designing and building to it is not new. It is common, for example, for developers to base the allowable cost of their projects on lease rates and their cost of capital. However, TVD aligns the commercial interests of the project-delivery and supply chain participants by means of incentives that create a win-win situation for all involved while aiming to optimize the whole.

TVD, as practiced in the AEC industry today, reflects an evolution of practices over the course of at least 20 years.

- As far as we know, the first project on which target costing (though not termed target costing) was successfully applied in the construction industry was BP's Project Andrew, an offshore platform in the North Sea (Knott 1996).
- The North Sea experience, including target costing, evolved into project alliancing in Australia (Ross 2006) and is now in use in other parts of the world.
- *Integrated Project Delivery*, the name of a company formed in the late 1990s (Matthews et al. 2003, Matthews & Howell 2005) followed the principles of TVD. The company consisted of architectural and engineering firms, a general contractor, and various specialty

contractors that conducted business together while sharing risks and rewards. As such, *Integrated Project Delivery*'s company practice typifies what might be called—to coin a term—"Collaborative Design-Build." In contrast, "normal" Design-Build does not involve sharing of risks and rewards.

- In 2002, manufacturing's target costing was for the first time deliberately and successfully applied to a project, St. Olaf College's Fieldhouse Project (Ballard & Reiser 2004). That Design-Build project was led by Boldt Construction and Ellerbe Becket.
- In 2003, Will Lichtig, at that time serving as outside counsel for Sutter Health, authored the Integrated Form of Agreement (IFOA) (Lichtig 2006). The IFOA is a form of relational contract, signed by the owner and the key AEC companies on the project, with shared risks and rewards and prescribing the use of lean management methods, including target costing.
- In 2005, the Project Production Systems Laboratory (P2SL) at the University of California, Berkeley, published a Target Costing Process Benchmark, which was updated in 2009 (Ballard 2009, 2011).
- In 2007, inspired by the IFOA, a set of contracts was published by ConsensusDocs (https://www.consensusdocs.org/) as their series 300 for integrated project delivery projects. ConsensusDocs was formed by a group of 40+ construction industry associations, not including the American Institute of Architects.
- "Integrated Project Delivery" (IPD) was used by the American Institute of Architects to name multi-party contracts that include the buyer together with key constructors in the design process, but do not require use of lean management methods (AIA 2007a, 2007b, Dal Gallo et al., no date).
- "Lean IPD" is used to name a form of project delivery in which lean management methods are used in tandem with the AIA requirements, whether or not they are contractually required.
- Alignment of commercial interests through shared risks and rewards (the so-called risk pool[3] including companies that have their profits at risk), organizational integration, and the use of lean management methods can be applied to a variety of contractual arrangements. It has become common to refer to projects with these characteristics, but that do not involve multi-party contracts including the buyer, as "IPD-ish."

[3] Companies not in the risk pool may be included in TVD teams but will be driven by different incentives.

- In 2007, the name “target value design” was coined by Hal Macomber and John Barberio (Macomber & Barberio 2007, Macomber et al. 2012) of Lean Project Consulting to denote the application of TC specifically in AEC project settings. Their white paper articulated nine practices that are different from conventional project management, but needed to create “the conditions for delivering the target value from the design process:
  1. Engage deeply with the client to establish the target value. Both designers and clients share the responsibility for revealing and refining concerns, for making new assessments of what is value, and for selecting how that value is produced. Continue engaging with the client throughout the design process continue to uncover client concerns.
  2. Lead the design effort for learning and innovation. Expect the team will learn and produce something surprising. Establish routines to reveal what is learned and innovated real-time. Also expect surprise will upset the current plan and require more re-planning.
  3. Design to a detailed estimate[4]. Use a mechanism for evaluating design against the budget and the target values of the client. Review how well you are achieving the targets in the midst of design. When budget matters, stick to the budget.
  4. Collaboratively plan and re-plan the project. Use planning to refine practices of coordinating action. This will avoid delay, rework, and out-of-sequence design.
  5. Concurrently design the product and the process in design sets. Develop details in small batches (lot size of one) in tandem with the customers (engineer, builders, owner, users, architect) of the design detail. Adopt a practice of accepting (approving) completed work as you design.
  6. Design and detail in the sequence of the customer who will use it. This maintains attention to what is valued by the customer. Rather than doing what you can do at this time, do what others need you to do next. This leads to a reduction in negative iterations (Ballard 2000).

[4] “Detailed” here does not mean that the cost estimate is based on a product breakdown, down to cost of nuts-and-bolts. Rather than stem from a design, cost estimating models that support TVD must express the voice of the customer. They may be parametric in nature or aim to reflect, e.g., value-in-use by describing functionality and design intent, so that they can inform the TVD team from the project definition phase onward (e.g., Morton 2008, Pennanen 2004, Pennanen & Ballard 2008, Ballard & Pennanen 2013).

7. Work in small and diverse groups. Learning and innovation arises socially. The group dynamics of small groups—8 people or less—is more conducive to learning and innovating: trust and care for one another establish faster; and communication and coordination are easier.
8. Work in a **Big Room**. Co-locating design team members is usually the best option. Design is messy. Impromptu sessions among design team members are a necessary part of the process. So are regular short co-design sessions among various specialists working in pairs.
9. Conduct Retrospectives throughout the process. Make a habit of finishing each design cycle with a conversation for reflection and learning. Err on the side of having more retrospectives not less. Use **plus/deltas** at the end of meetings. Use more formal retrospectives that include the client at the end of integration events. Instruct all team members to ask for a retrospective at any time even if they just have a hunch that it might uncover an opportunity for improvement."

This quote highlights key TVD methods and practices but, as our chronology suggests, TVD continues to evolve. Section 4 in this document presents the current benchmark for practice. Through further research and application, new methods and practices have emerged over time and will continue to emerge to augment TVD as we know it today.

1.3 TVD Process Overview

TVD can be applied to many types of capital- or other projects, big and small. It can focus on tracking the capital cost of a project or performance against other targets such as operational costs, full-time equivalent staffing count, sustainability, and schedule. Figure 1 illustrates that its application extends throughout the project: targets are set in project definition, then design is steered to targets, and finally construction is steered to targets.

TVD in the broad sense stands for Target Value *Delivery*, including not only design but also operations, maintenance, and decommissioning. The term *Whole Life* TVD amplifies this soup-to-nuts application of TVD, in which targets are set not only for first cost but also for the net benefits of asset use (including, e.g., evolving customer purpose and sustainability considerations).

Targets are set for program and scope (what the client wants in order to accomplish their objectives) and for constraints such as money and time that must be met in delivery of the project. Specification of what is needed (must-have criteria) limits the set of possible designs, which is called the "design space" or sometimes the "solution space." Specification of what is wanted (want criteria) helps gauge the differences between attributes of design alternatives (the advantages of each relative to a least preferred one). Preferences (expressed in "importance of advantages") then enable selection of the best design from within the set.[5]

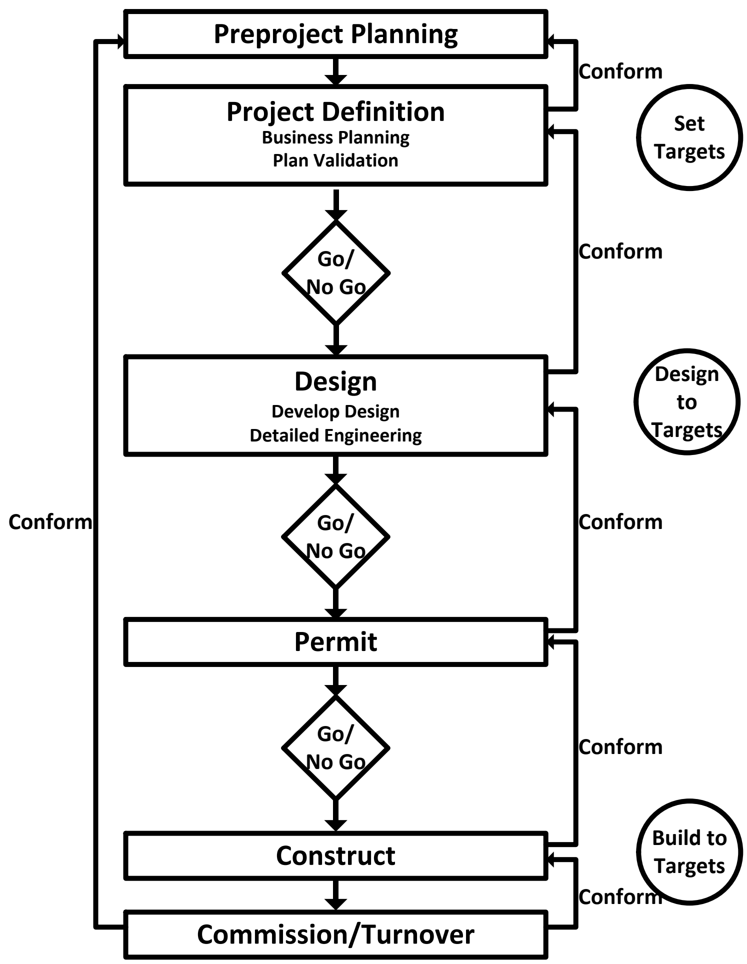

Figure 1: Scope of Target Value Design (Ballard & Morris 2010)

EXAMPLE: Suppose a customer wants a building for her computer graphics company. She specifies where it is to be located, how many workstations are to be provided, and what the maximum price and desired completion date are. Many different building designs may satisfy this customer "demand." She also expresses a preference for low environmental impact during

5 The terms "alternative," "must-have criterion," "want criterion," "advantage," and "importance of advantage" stem from the Choosing By Advantages (CBA) decisionmaking system (Suhr 1999).

business use of the building. This preference allows the project team that includes the customer to differentiate between otherwise acceptable designs and then choose the best one for her.

TVD may be applied in a number of different project delivery processes, not exclusively those pursuing IPD to deliver capital projects (e.g., Collaborative Design-Build team may use TVD). The key is for the project team to find a way to make the TVD process "work" with as goal to significantly improve customer value decision making for a better overall outcome thanks to—or perhaps despite—the commercial terms that ties them together. While setting individual targets and using "local TVD" can be valuable, maximum benefit is derived from total value stream optimization. This requires a significant shift from traditional thinking and best results are gained if the commercial terms incentivize this.

The essential ingredients for making the TVD process work are the team's ability to:

1. integrate early,
2. manage product and process design concurrently, leveraging team members' combined product- and process familiarity jointly with historic cost knowledge and design experience to bring credibility to detailed estimates and design alternatives, and
3. share risks and rewards, with targets aligned to optimize the whole.

While anyone with cost risk for any project phase or deliverable can practice aspects of TVD, at the heart of a TVD project is that all key members share risks and rewards for all costs they can control. This sharing is what drives people from their standard practice of optimizing their own scope of work towards developing the best project overall.

TVD may also be applied in processes that are not traditional capital projects at all; e.g., mortgage financing of energy retrofits (Lee et al. 2011; Lee 2012) and development of competitive proposals (Lee et al. 2012).

1.4 How TVD Differs from Common Practice

Defining what customers need to accomplish their objectives and the constraints (e.g., money and time) on acceptable means would seem to be a starting point for all projects, but common practice is very different. Frequently, customers specify the solutions to their problem without sharing their objectives. This transactional approach to contracting (as opposed to a relational approach) conceals the information needed by service providers to provide value to their customers.

Setting budgets sufficient to enable achievement of project objectives while incentivizing delivery of acceptable means for less money may also appear to be common sense but, here too, common practice is very different. Frequently, customers try to spend the least amount of money to get what is wanted. This increases the risk that project objectives will be compromised.

A cardinal rule in TVD is that targets can never be exceeded, and only the customer can change the target scope, quality, cost, or schedule. This rule can be valid only when the project owner jointly with their TVD team have invested the effort needed to develop a validated and justified budget to deliver the desired program in the chosen marketplace.

Steering to targets is another practice that seems to be common sense, but that is uncommon in practice. On most projects, cost estimates increase as design becomes more complete, and often exceed budgets. This outcome is the result of updating cost estimates too irregularly and infrequently, lacking up-to-date market data available from suppliers and builders (on costs, lead times and availability, newly introduced product or process innovations, etc.), together with adversarial relationships between customer and service providers, each of whom have very different commercial interests.

1.5 Why Do TVD?

1.5.1 Using TVD in Pursuit of the Lean Ideal

TVD is a method for pursuit of the lean ideal: provide customers exactly what they need to accomplish their purposes, with no waste. The balance of risks and rewards between customer and service providers makes it attractive for the project team to set reasonable stretch goals[6], preserving scope-, time-, and cost certainty while pursuing continuous improvement.

1.5.2 Why do Buyers use TVD?

TVD is suited for buyers who want to maximize their asset within a defined budget or constraint, but it is not done unilaterally, most notably because value is not simply additive, the

[6] Using lean thinking (e.g., by articulating value and rooting out waste) TVD teams may achieve cost reduction and other goals without much if any “stretching” (also see Markovitz 2012).

relationship between value and money is not linear (Johnson & Bröms 2000)[7], and the supporting knowledge is dispersed among project team members. Accordingly, owners must be willing to engage with their project participants in this balancing act—without getting greedy—first when setting scope and budget, and later when delivering value to target.

TVD is especially well suited to repetitive buyers of constructed assets because (1) they are more likely to be able to participate actively and productively in project delivery, (2) they benefit from continuous improvement not only within each project but also from project to project, and (3) they have the confidence and internal trust borne from repeated projects within a mature capital program.

What do owners think about the quality of their TVD projects?

"Out of the 50 TVD projects that we have completed since 2005, we have been able to consistently deliver projects for 15% below the market price. Quality, schedule, and scope were not compromised in the process." – Private Owner 1

"The most important thing about TVD/IPD is that we are able to get what we want with sacrificing on one or more dimensions of project success (scope/quality, cost, schedule). The owner has more control over his project because he can be engaged throughout the process." – Private Owner 2

"The most important thing about TVD/IPD-ish is that we are able to make value-added changes without having to make a change to the contract or go through the change order process. For a hospital project that take between 5 to 10 years, change is inevitable. I can't image how we would be able to delivery just a project with the traditional project delivery method [DBB]." – Public Owner

1.5.3 Why do Service Providers use TVD?

Architects, engineers, general contractors, specialty contractors, and other project supply-chain participants also benefit in many ways from using TVD: They enjoy a much better quality of working life. They are challenged to develop their skills and broaden their minds to new ideas. They work collaboratively with and learn from other professionals.

7 So-called value engineering that results in cost-cutting done late in the design process tends to result in a disproportionate loss in value.

Companies providing AEC services also experience commercial advantages: Thanks to integrated team work, they reduce their risk exposure due to out-of-sequence decisions or outdated cost information. Thanks to award of work further in advance, they can better plan manpower and equipment use, and offer far more input on work planning. Furthermore, they can create longer-term relationships with the client and lower their cost of acquisition of work (less marketing).

Experience has shown that collaboration in the effort to meet targets yields better than normal profits with less downside risk and less stress on participants. At their best, high performing TVD teams drive much innovation into projects, one of the key personal motivators for design professionals.

1.5.4 Sample Benefits of Using TVD

When properly implemented[8], TVD is beneficial to all parties. Waste is reduced and innovation (value creation) is promoted. Owners get what they need within their willingness and ability to pay. Service providers earn more when they increase value or decrease cost.

"The owner and contractors' involvement during the design phase leads to less negative iterations and less guess work [waste]. On traditional DBB, we are not paid for the wastes because the owners do not see them. Even without considering profit, we are making 15% more on TVD/IPD because we are compensated for all of our hours." – Designer

"TVD/IPD leads to more thought out plans for the construction phase. The fact that we are reimbursed for our cost is the project goes over budget and we share in the savings means that people are more willing to try innovative ideas. Everyone does what is best for the project rather than try to hoard scope." – General Contractor

"On a large project, you are not betting the company's financial future. It typically takes 5 to 10 good jobs to cover the losses of 1 bad job. Instead of focusing on how to protect for self when there is a claim, you are focused on the project and on delivering value to the client." – Subcontractor

"TVD/IPD allows me to have a better working relationship with the other trades and is a good process for business development." – Architect

[8] Advice regarding prerequisites and preparation is provided in a later section titled "Getting Started."

"The personal satisfaction of a high performing TVD team is really really high – each partner brings their best game; the results are tangible, real and meaningful." -- *Architect*

2 Scope of this TVD Document

This TVD Document describes the process of setting targets and then designing to those targets in all phases of project delivery (Figure 2).

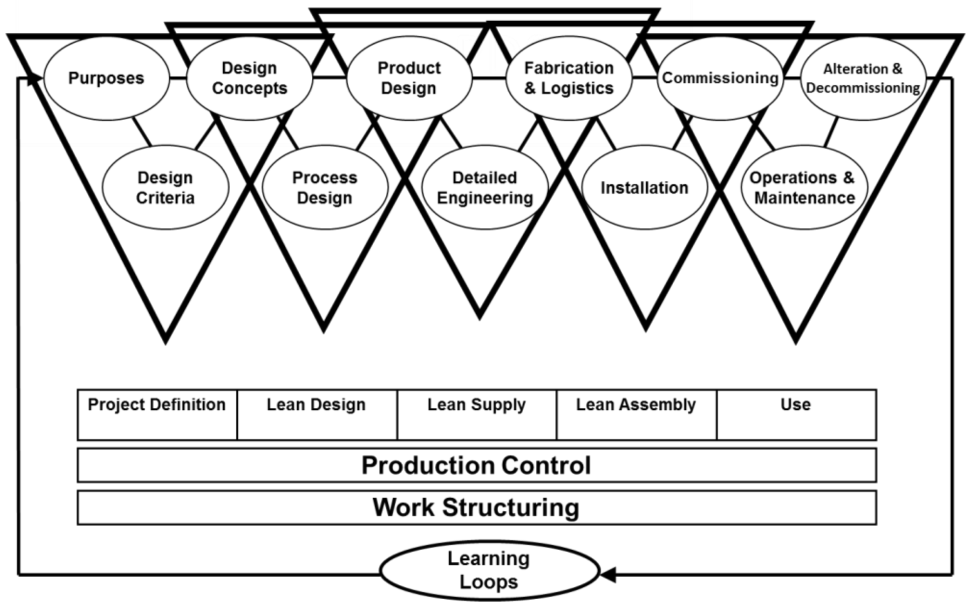

Figure 2: Lean Project Delivery System

It assumes that TVD is applied in a project where all three essential TVD ingredients are present: (1) early integration, (2) concurrent product and process design, and (3) risks and rewards sharing. Clients may be included on the team, as is the case in IPD, or may be excluded from the team, as is the case in Design-Build (perhaps more so in public- than in private sector projects). For Design-Build projects, it is assumed that the companies doing design and construction share risks and rewards as indicated by the term "Collaborative Design-Build," rather than fall back—despite their DB agreement—to adopting the roles they traditionally take on in a DB project.

The document is written with two audiences in mind: (1) owners who want to implement TVD on their projects and (2) project delivery team members who want to know how to go about it.

3 How to do TVD

3.1 Defining Owner Value

TVD starts with the owner fully committing to being engaged in the process and initiating the use of TVD in project definition. Owner commitment and involvement are crucial to driving success.

An essential ingredient in TVD is that the owner must be able to specify what constitutes value to them (so-called “fitness for purpose” or “value in use”), their aspirational goals vs. **conditions of satisfaction** (**COS**), and make clear to the team how they will measure these. This may be done using performance specifications (must-have criteria) and performance metrics (want criteria) so that “value for money” can be assessed (measured as objectively as possible) and trade-offs made by the team comprising owner and service providers (designers, engineers, builders, and others on the delivery team) while generating and selecting from product and process design alternatives.

A challenge in characterizing value is that an owner organization can have many faces (e.g., in case of a hospital, it includes the patients, relatives and friends of patients, healthcare providers, facilities maintenance personnel, regulatory agencies, etc.) each one with values that potentially compete with those of others. Another challenge is that the owner’s understanding of value may change in the course of exploring alternatives in the TVD process. By having a representative with decisionmaking responsibility and authority on the project delivery team, who is also accountable to the team, the owner will be well positioned to address those challenges as they arise.

The same must be said of commitment and involvement required of others on the IPD team, not just the owner, and the need to define what constitutes value and makes up COS for each of them individually and the team as whole. Furthermore, IPD team participants engaged in TVD must be encouraged to revisit these as their project progresses and its delivery context changes.

EXAMPLE: The University of California, San Francisco (UCSF) invested upfront a `considerable amount of time and money in defining value to be delivered by their Mission Bay Block 25 Building (Bade & Haas 2014). UCSF wanted a high degree of certainty that the building would be (1) completed on time, (2) support the emerging research, teaching, and patient care community, and (3) have a long-term value horizon. To obtain high certainty of *outcomes, UCSF agreed to trade control of the process for the pursuit of performance objectives that deliver long-term value (Table 1). A design firm helped develop a value book with 250 different measurement points in advance of selecting a project delivery team (Table 2).*

UCSF then selected a performance-based Design-Build delivery system to engender innovation in design and construction (note that the University of California is not legally allowed to enter into multi-party contracts so it cannot pursue IPD as such) and hosted a design-build competition. Competitors were to deliver a fixed program (including furniture and IT) at a fixed cost. The owner would evaluate proposals based on a three-level performance specification and award the project to the best value team.

The winning team clearly "heard" the owner, thought comprehensively about whole systems and their interactions, and understood the operational consequences of their design. They completed the project well on time and within budget, with the desired "asset performance," thus delivering a project the owner is very pleased with.

PROJECT GOALS

A Quality Work & Learning Environment	A Model of Architectural & Urban Design	A High Performing Building	Environmentally Sustainable	Durable & Long-lasting	Efficiently Serviced & Maintained

BUILDING EXTERIOR	• Design the identity and urban presence of the building to reinforce UCSF's mission of caring, healing, teaching and discovering. • Develop passionate, innovative, contemporary yet timeless architecture through the composition of architectural elements and arrangement of materials. • Imaginatively reinterpret the context of the UCSF campus and city through architectural design. • Employ high performance design and innovative sustainability strategies to enhance the experience and productivity of the building users. • Create meaningful spatial interactions between indoors and outdoors to enrich the experience of the building occupants, members of UCSF, and the public.
BUILDING INTERIOR	• Support UCSF's mission of excellence in academics, health care research and clinical care by developing a gathering place that facilitates a rich professional and community life. • Foster an interactive, collegial, and collaborative environment that fuses the clinical programs with dry, basic and translational research. • Set a model for the future of UCSF workplace through an Activity-Based Workplace tailored to the function, activities, and tools of UCSF faculty, staff and students. • Achieve optimal efficiencies in the use and organization of space, circulation and core functions. • Integrate building functions, technology and systems for high performance, maximizing function, serviceability and durability. • Connect the exterior, interior, office and learning program elements to create a rich and full experience for the building users. • Design the building interior to be imaginative, contemporary yet timelessly elegant, cohesive and meaningfully transparent.
01 Energy & Resource Efficiency	Design a project that integrates all systems to provide a high-performing building that is appropriately controlled and monitored to minimize energy and resource consumption.
02 Structurally Sound	Develop a code-compliant, safe building that can withstand major seismic events. Provide an efficient structural system that is integrated with the proposed spatial and building systems and that can efficiently adapt to changing office use requirements and infrastructure improvements, while fulfilling or exceeding required performance standards.
03 Climate Responsive	Provide a building that is weather-tight while making maximum use of day-lighting and natural ventilation. Design site utilities, plantings, and site drainage to respond to the specific climactic and soil conditions of the Mission Bay environs.

Table 1: Project goals for UCSF Block 25

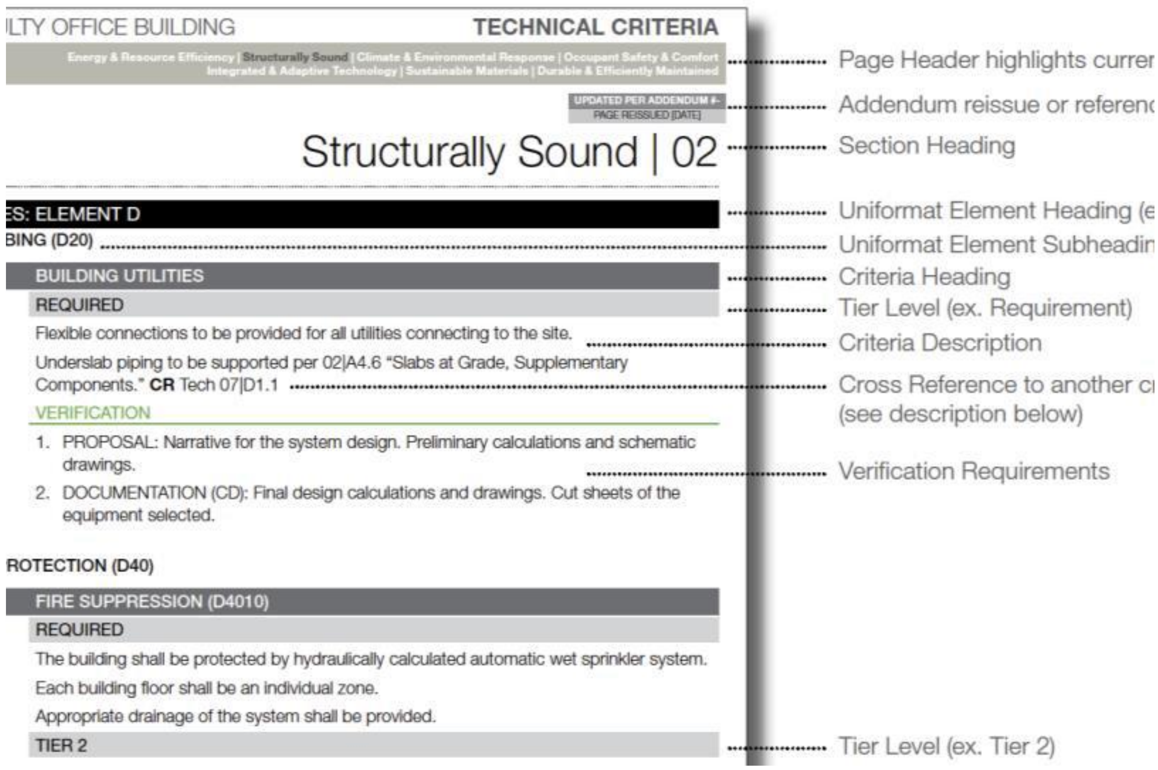

Table 2: Excerpt from performance specifications developed by UCSF consultant

3.2 Project Definition

Project Definition includes business planning and business plan validation (done by the client in collaboration with a project team), and concludes with the client deciding to abandon a project or to fund it, incrementally or completely.

3.2.1 Business Planning

The first step in Project Definition (the first triad in Figure 2) is business planning. Figure 3 shows that this involves an assessment of the worth[9] (or value to the client) of the facilities being considered, just the same as manufacturers do when planning to develop a new product. From that assessment of worth and a minimum acceptable return on investment, the client can determine what they are willing to pay. That number is tested against their ability to fund, which yields the **allowable cost (AC)**: the most the client is able and willing to pay.

[9] Asset worth may be determined using an operations cost model, at least for assets that are themselves means of production.

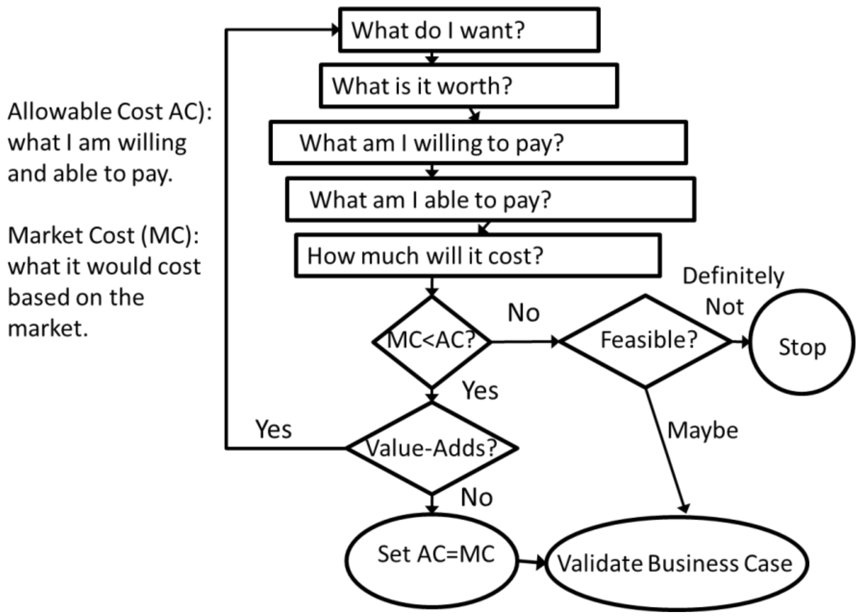

Figure 3: Process for deciding if to fund a validation study (Ballard 2012)

Business planning is led by the client's in-house staff. Design and construction professionals cannot provide much help with demand forecasting and prioritizing capital allocation. Further, clients may want to keep certain business information confidential. However, by revealing the assessment of worth and allowable cost, the client builds trust and enables the team to better evaluate the probability of overcoming a negative gap between the team's ***expected cost (EC)*** (explained later) and the client's allowable cost[10], and to make better design decisions based on value trade-offs when projects are validated and move into design.

Continuing to follow Figure 3, business planning includes a comparison of the allowable cost to the ***market cost (MC)***[11], an estimate based either on costs of similar projects already completed (benchmarking) or on cost models responsive to the voice of the customer. If allowable cost exceeds market cost (AC > MC in Figure 3), the project is financially viable,

10 An owner can pose a target cost without revealing its relationship with their allowable cost, but that may conceal the extent of risk to the delivery team. Suppose the target cost is 10% below the benchmark market cost (MC), and the allowable cost is 5% below the MC. If the target cost becomes budget, shared savings starts at 10% below market. If the allowable cost were to become the budget, shared savings would start at 5% below market.

11 The accuracy of conceptual cost estimates (made prior to design) can be much improved with the use of cost models at the component level of detail, responsive to the voice of the customer. Preliminary research suggests an accuracy of ±12.4% at two standard deviations; i.e., 95% confidence level. One example of an approach that results in achieving such accuracy in conceptual cost estimating is offered by Haahtela's TaKu (Ballard & Pennanen 2013).

and the client may choose to increase scope to get more value from the investment. If market exceeds allowable (AC < MC), viability is in doubt[12]. If the gap is too large, the client may revise scope to reduce or eliminate the gap, or may choose to kill the project. If the client judges that the gap is possible to close, the key companies that will design and construct the project if validated are engaged to validate the business plan.

3.2.2 Business Plan Validation

The second step in Project Definition is business plan validation. The IPD team typically gets engaged at this point and in this step produces a conceptual design, including at a minimum a (massing) model with functions allocated to spaces, and basis of design documents for all major systems. With this additional detail about the asset to be delivered, the team can apply its knowledge, experience, and shared understanding to produce an ***expected cost (EC)*** and compared it to the client's allowable cost. Comparison and options reoccur as previously described. The plan validation report includes the conceptual design, the comparison of expected and allowable cost, and the team's recommendation to continue, with either complete or partial funding, or to revise/abandon the project (the first Go/No Go diamond in Figure 1). The team's decision reflects their confidence (a kind of risk) that they can deliver what the client wants within client constraints of cost and time, while preserving the team's profits. We might say that the team is making a promise, and placing their profits at risk as surety.

A brief review of commercial terms on IPD projects: Profits of risk pool members (companies that have their profits at risk) are negotiated after the decision to fund/not fund the project (see next section), but the team understands at validation that those profits will be included within the project budget, which covers the cost of work, including overheads, and profits. The cost of work for these companies is reimbursed by the client. Should the actual cost of work exceed the amount budgeted, the excess reduces the profit pool, and when that pool is exhausted the client pays any remaining costs in excess of budget. Consequently, a validation study is appropriate only when the companies that do the study share project cost risk and have some control over design, as is the case in Integrated Project Delivery (IPD) and in Collaborative Design Build projects. In IPD projects, it is common for the key members of

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[12] In some cases, project scope is inflexible; e.g., when a permit-dependent upgrade is required for a production facility. When the market cost exceeds allowable cost, neither the option to reduce scope nor the option to kill the project is available. The only option is to proceed with the project, incentivizing design innovation and waste reduction in its delivery.

the project team of designers and builders to be reimbursed for their cost of work, but to have their profits at risk for hitting targets (they are in the risk pool). In contrast, in traditional DB projects, cost risk is typically shifted from client to the design builder. "Selling" risks (rather than sharing) impedes the applicability of TVD.[13]

3.2.3 Deciding if to Fund a Project

If allowable cost is less than expected cost (AC < EC), both client and risk pool members must discuss, revisit, and agree to targets and commercial terms in order for the project to proceed to funding. These discussions may force the client to face difficult value decisions and restate the project goals, while the team may offer design alternatives and re-assess their plan validation.

An alternative is for the client to engage different designers and builders in hopes they will have a different assessment of risk or expectation of returns. However, on IPD projects, clients bear the risk of costs exceeding profits of the companies in the risk pool. This tends to restrain clients' search for designers and builders willing to take on more risk because the client shares in that risk. That same restraint is absent from the traditional DB situation, where the design-builder assumes all cost risk. However, even in that situation, the client still bears the risk that a design-builder may be unable to complete the project or will reduce value delivered to the client in attempts to reduce their own costs.

Note that the feasibility of reducing the project cost to or below the allowable cost may be in such doubt that the client chooses to fund design to that point at which feasibility can be determined.

3.2.4 Target Setting and Commercial Terms

The budget is the dividing line between profit and loss on both IPD and DB projects (Figure 4). On IPD projects, the budget includes the cost of work (COW) and profits. The COW is reimbursable. If the cost at completion exceeds the amount budgeted for the COW, profits are reduced to pay those costs (shown on Figure 4 by "Painsharing"). The client is at risk for budget overruns; i.e., when the actual COW exceeds the amount budgeted for the COW plus profits.

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13 In CM@Risk projects, the CM firm bears cost risk for construction, but shifts cost risk to subcontractors to the extent feasible, and hence violates the assumption that at least the key members of the project team share risks and rewards. Further, specialty contractors are not involved in design, and the CM does not participate directly in design, only providing cost estimates and constructability reviews.

If the cost at completion is below the COW, savings are shared (shown on Figure 4 by "Gainsharing"), in some cases limited to a maximum amount.

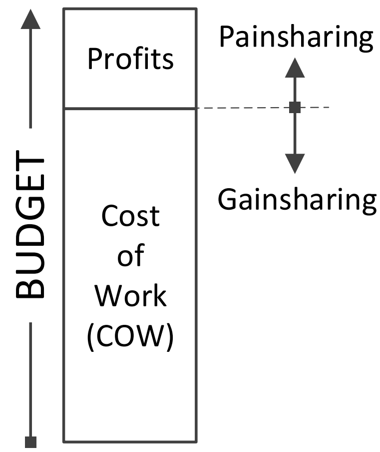

Figure 4: TVD commercial terms with pain- vs. gainsharing

IPD teams will be driven to pursue savings that reduce the COW especially when commercial terms incentivize them to meet and surpass their agreed-to targets (e.g., Ashcraft 2010, no date). Shared savings will encourage the owner to remain fully engaged with everyone else on the team to drive out waste, achieve efficiencies, and optimize their project, thereby realizing a win-win-win situation for all involved.

On DB projects, the design-builder has a fixed price budget for project delivery. If profits are included in the fixed price, they can be increased through cost savings. Otherwise profits are entirely dependent on cost savings and the design-builder is at risk for budget overruns.

3.3 Steering Design to Targets

Steering to targets is done throughout the project, during Design, Supply, Assembly, and Close out (Figure 1), and involves (1) how the project is organized; (2) how product and process design is developed, alternatives selected, and documented; and (3) how information is shared, how the culture of collaboration and innovation is promoted, and how the work is planned and controlled.

3.3.1 Project Organization

In Design, TVD projects are organized in cross-functional teams based on facility systems and the processes that will eventually be used to construct those systems. Typical TVD teams for a building project include:

- Architectural
- Structural
- Mechanical
- Electrical
- Envelope
- Interiors
- Offsite prefabrication and preassembly
- Logistics
- Site construction

Each team has the relevant specialists (signatory to the multi-party contract such as the IFOA, if there is one, but also others) plus a representative of the firm playing the role of project manager and a representative of the architect or lead engineer. Team composition aims at bringing together expertise as well as create opportunity for innovation (e.g., as outsiders sometimes can bring). For example, relevant specialists for a Structural TVD team would include the structural engineer, structural fabricator, and structural erector, some perhaps joining the team later than others. It would also include others who are normally not in a position to give direct input (e.g., interior designers making flooring decisions that require altering the slab, medical equipment planners making choices that have a direct impact on loading) but who have a key role to play in the success of that team. Where possible, the team would also integrate inspectors as well as contractors to provide their input into the design of products and processes.

Teams may also be organized programmatically or operationally (e.g., clinical space, procedural space or patient experience, and supply chain). Team leaders are typically selected based on knowledge and communication skills. A key aspect of TVD is that the team leaders communicate with each other offline, in-between integration events.

Each team is expected to have estimating capability. Within a team, whoever can provide the best estimator provides the estimator. At the onset of design, the target cost gets broken down into sub-budgets, each one allotted to a team. Teams are then tasked with designing their subsystem(s) and innovating best they can so as to realize the project scope while meeting all requirements, including their target cost budget. However, not all designs and innovations can be funded using only the team's sub-budget. *A key to the success of TVD is that money must be able to flow across boundaries:* if one team incurs a cost overrun, the needed money must be freed by other teams (and compromise mediated when necessary) so as to prevent that the project would exceed its target cost while optimizing the whole. As mentioned, the cardinal rule in TVD is that targets can never be exceeded, and only the customer can change the target scope, quality, cost, or schedule.

3.3.2 Product and Process Development using Set-Based Design, Choosing by Advantages, and A3 Problem Solving

TVD is supplemented by three connected management methods: (1) Set-Based Design, (2) Choosing by Advantages and (3) A3 Problem Solving.

3.3.2.1 Set-Based Design (SBD)

Set-Based Design (SBD) is a method that includes exploring the design spaces (sets of alternatives) for parts of the problem (e.g., subcomponents), using set intersection to generate alternatives for the problem as a whole, and deferring decisions among them until the **last responsible moment (LRM)** (the moment at which an alternative becomes no longer viable) in order to find the best combination that solves the problem as a whole. Early identification of acceptable, though not optimal, alternatives prevents slipping into the first irresponsible moment.

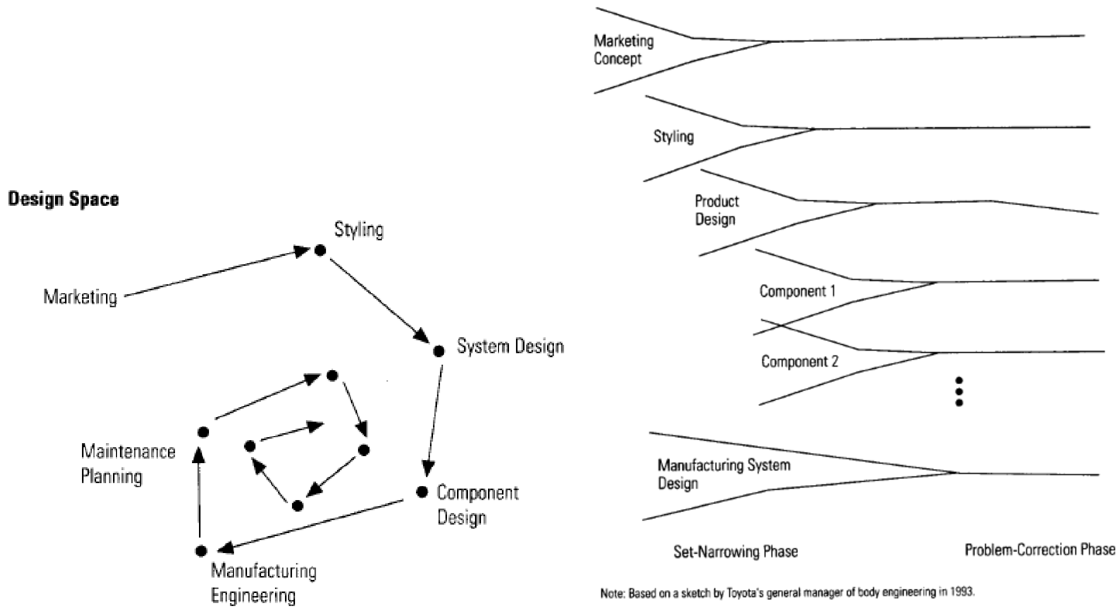

Figure 5: Point-based design (left) vs. set-based design (right)
(Figures from Ward et al. 1995)

The practice of set-based design contrasts with the all too frequently pursued design method called point-based design; both illustrated in Figure 5. Point-based design is a method whereby one specialist explores (one or a few alternative) solutions to their part of the problem, selects one, and then passes that one to the next design specialist. This early and piecemeal selection of partial designs—deemed optimal from one specialist's perspective—may overly restrict the alternatives available to designers engaged later in the process. If those later designers cannot find a satisfactory solution, the process may have to iterate, thereby wasting time and effort. Even if they can find a way to make their part of the design work, this process seldom if ever leads to a design that is best for the project overall.

Set-based design is a method that aligns with the following lean principles:

- Avoid rework and iteration by considering sets of design alternatives.
- Engage all stakeholders in the process of defining alternatives and include as decision factors and criteria what is important to them.
- Promote innovation when exploring alternatives.
- Pursue single piece flow: plan decision points in a project so as to meet the needs of team members' and the clients' last responsible moment. This enables them to make

smaller decisions throughout the design process (and thus avoid rework), instead of bigger decisions later on (e.g., all at once at a SD or DD review).

- Share incomplete information often, view alternatives across disciplines (avoid local sub-optimization).
- Defer decisionmaking until as many relevant facts as possible are known, and decide at the last responsible moment.

3.3.2.2 Choosing By Advantages (CBA)

Choosing By Advantages (CBA) includes a set of methods[14] for selecting from alternatives when multiple factors and criteria are relevant to evaluating and differentiating the alternatives (www.decisioninnovations.com/, Suhr 1999). These methods are set-based in that they rely on exploring alternatives and deferring selection until the last responsible moment. Figure 6 illustrates the steps of one method of CBA, the Tabular Method. CBA methods are particularly well-suited to support argumentation (Arroyo et al. 2014) and consensus-based[15] group decisionmaking as they help create transparency and thus an auditable decision process (Mossman 2013).

CBA decisionmakers recognize that all decisions are subjective and depend on the context in which they are made. They must be grounded in project values. This context is therefore documented using factors, criteria, attributes, advantages, and importance of advantages. Figure 6 shows that, while steps 1 through 6 in the Tabular Method aim to articulate value (an internal, personal matter), step 7 brings in the monetary aspects (related to external, market conditions, e.g., price). As contexts change, the method recognizes the need for reconsideration (the arrow going from step 7 back to step 1 illustrates this iteration).

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14 CBA methods are Multi Criteria Decision Making (MCDM) methods.

15 Though consensus is not necessarily required when using CBA to make a decision.

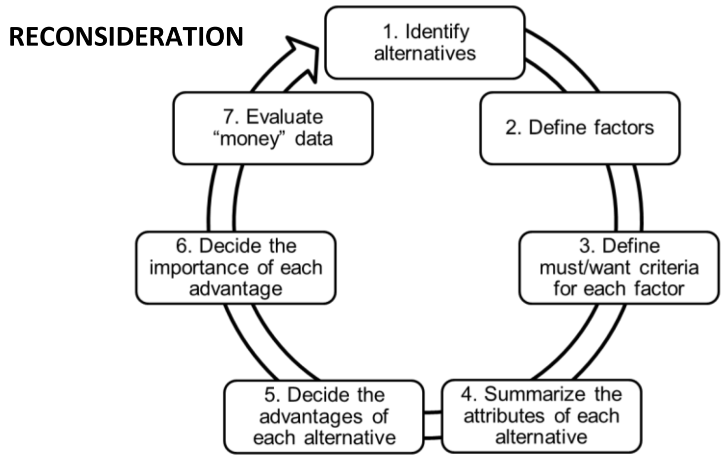


Figure 6: Steps of the Tabular Method of Choosing By Advantages (CBA)

Suhr (1999) articulated 7 principles on which CBA methods are based, e.g., to name some: Principle 1: Decisionmakers must learn and skillfully use sound methods (The pivotal cornerstone principle), Principle 2: Decisions must be based on importance of advantages (The fundamental rule), and Principle 3: Decisions must be anchored to the relevant facts (The principle of anchoring).

Equally important is that CBA is aligned with lean principles:

- Promote transparency and standardization in decisionmaking.
- Include all stakeholders and consider multiple views in the consensus building process.
- Base decisions on the relevant facts.
- Address the more objective aspects of decisionmaking before the more subjective ones (that is, define alternatives and their attributes separately from the factors and criteria to discriminate between them).
- Postpone value judgment (especially the assessment of importance of advantages) until the last responsible moment.

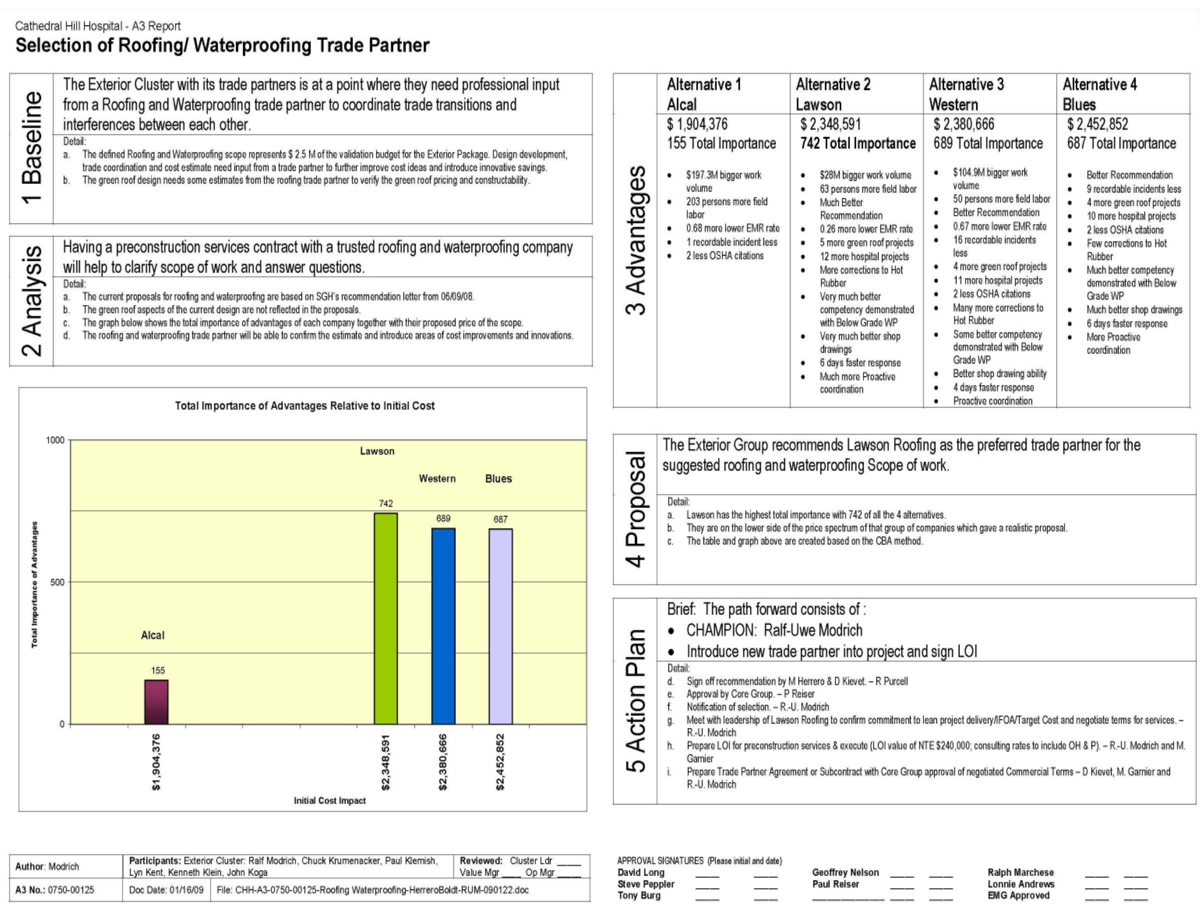
CBA is being used on a number of projects and in many different contexts, e.g., Arroyo et al. (2015) illustrate its use when selecting ceiling tile with global sustainability in mind.

3.3.2.3 A3 Problem Solving

A3 problem solvers follow the discipline of scientific experimentation using the Plan-Do-Check-Act (PDCA) method for learning and continuous improvement (www.montana.edu/dsobek/a3/, Gupta et al. 2009, Shook 2009), and summarize their reasoning on a single sheet of paper of A3 size (297 mm × 420 mm or approximately 11" x 17"). A problem solving A3 includes the background, problem statement, analysis, proposed corrective actions (and the action plan), and the expected results, often with graphics.

A3 reports can be used as a standard method for summarizing design efforts (e.g., analysis of **TVD** options and **CBA** graphs proposing that a specific alternative be selected), status reports, and planning exercises. They are generated through a process of consensus building that prompts thorough understanding of the current situation (the facts) and systematic experimentation and learning.

Figure 7 shows an A3 developed to select a trade partner to provide roofing waterproofing. The section "1 Baseline" presents the issue to be addressed. "2 Analysis" offers the rationale why the issue must be addressed. "3 Advantages" presents a summary of the CBA analysis; an appendix (not shown) to this A3 offers the details.


Cathedral Hill Hospital - A3 Report

Selection of Roofing/ Waterproofing Trade Partner

1 Baseline

The Exterior Cluster with its trade partners is at a point where they need professional input from a Roofing and Waterproofing trade partner to coordinate trade transitions and interferences between each other.

Detail:

a. The defined Roofing and Waterproofing scope represents $ 2.5 M of the validation budget for the Exterior Package. Design development, trade coordination and cost estimate need input from a trade partner to further improve cost ideas and introduce innovative savings.

b. The green roof design needs some estimates from the roofing trade partner to verify the green roof pricing and constructability.

2 Analysis

Having a preconstruction services contract with a trusted roofing and waterproofing company will help to clarify scope of work and answer questions.

Detail:

a. The current proposals for roofing and waterproofing are based on SGH's recommendation letter from 06/09/08.

b. The green roof aspects of the current design are not reflected in the proposals.

c. The graph below shows the total importance of advantages of each company together with their proposed price of the scope.

d. The roofing and waterproofing trade partner will be able to confirm the estimate and introduce areas of cost improvements and innovations.

3 Advantages

Alternative 1 Alcal	Alternative 2 Lawson	Alternative 3 Western	Alternative 4 Blues
$ 1,904,376 155 Total Importance	$ 2,348,591 **742 Total Importance**	$ 2,380,666 689 Total Importance	$ 2,452,852 687 Total Importance
• $197.3M bigger work volume • 203 persons more field labor • 0.68 more lower EMR rate • 1 recordable incident less • 2 less OSHA citations	• $28M bigger work volume • 63 persons more field labor • Much Better Recommendation • 0.26 more lower EMR rate • 5 more green roof projects • 12 more hospital projects • More corrections to Hot Rubber • Very much better competency demonstrated with Below Grade WP • Very much better shop drawings • 6 days faster response • Much more Proactive coordination	• $104.9M bigger work volume • 50 persons more field labor • Better Recommendation • 0.67 more lower EMR rate • 16 recordable incidents less • 4 more green roof projects • 11 more hospital projects • 2 less OSHA citations • Many more corrections to Hot Rubber • Some better competency demonstrated with Below Grade WP • Better shop drawing ability • 4 days faster response • Proactive coordination	• Better Recommendation • 9 recordable incidents less • 4 more green roof projects • 10 more hospital projects • 2 less OSHA citations • Few corrections to Hot Rubber • Much better competency demonstrated with Below Grade WP • Much better shop drawings • 6 days faster response • More Proactive coordination

4 Proposal

The Exterior Group recommends Lawson Roofing as the preferred trade partner for the suggested roofing and waterproofing Scope of work.

Detail:

a. Lawson has the highest total importance with 742 of all the 4 alternatives.

b. They are on the lower side of the price spectrum of that group of companies which gave a realistic proposal.

c. The table and graph above are created based on the CBA method.

5 Action Plan

Brief: The path forward consists of :

- CHAMPION: Ralf-Uwe Modrich
- Introduce new trade partner into project and sign LOI

Detail:

d. Sign off recommendation by M Herrero & D Kievet. – R Purcell

e. Approval by Core Group. – P Reiser

f. Notification of selection. – R.-U. Modrich

g. Meet with leadership of Lawson Roofing to confirm commitment to lean project delivery/IFOA/Target Cost and negotiate terms for services. – R.-U. Modrich

h. Prepare LOI for preconstruction services & execute (LOI value of NTE $240,000; consulting rates to include OH & P). – R.-U. Modrich and M. Garnier

i. Prepare Trade Partner Agreement or Subcontract with Core Group approval of negotiated Commercial Terms – D Kievet, M. Garnier and R.-U. Modrich

Author: Modrich	**Participants:** Exterior Cluster: Ralf Modrich, Chuck Krumenacker, Paul Klemish, Lyn Kent, Kenneth Klein, John Koga	**Reviewed:** Cluster Ldr ____ Value Mgr ____ Op Mgr ____
A3 No.: 0750-00125	Doc Date: 01/16/09	File: CHH-A3-0750-00125-Roofing Waterproofing-HerreroBoldt-RUM-090122.doc

APPROVAL SIGNATURES (Please initial and date)

David Long ____ ____ **Geoffrey Nelson** ____ ____ **Ralph Marchese** ____ ____
Steve Peppler ____ ____ **Paul Reiser** ____ ____ **Lonnie Andrews** ____ ____
Tony Burg ____ ____ ________ ____ ____ **EMG Approved** ____ ____

Figure 7: A3 report for selection of waterproofing trade partner

The graphic comparing the importance of advantages to the price of each of the four alternatives is a product of CBA—allowing selection of the best value for money. “4 Proposal” summarizes the team’s recommendation and “5 Action Plan” spells out the steps for implementation of the decision. This five-step approach is but one of many ways to present the “story” of the learning done by a team.

A3s help to implement the following lean principles:

- Make the decision process visible.
- Get input from all relevant stakeholders, build shared understanding, and reach consensus.
- Document facts and the decision rationale.
- Pursue continuous improvement (PDCA).

3.3.3 Culture and Teamwork

Culture and teamwork practices establish how information is shared, how collaboration and innovation are promoted, and how the work is planned and controlled.

3.3.3.1 Information Sharing

An objective of TVD is to decide at the same time what is to be built and how to build it.[16] That requires close collaboration between architects, engineers, and constructors; one reason TVD teams are cross-functional. A challenge often met when the project team members are new to TVD is that constructors are impatient with the design process, and designers are insufficiently sensitive to constructors’ concerns for cost, time, and buildability. It is best to anticipate this challenge and invite all concerned to examine and revise their presuppositions.

Steering design to targets also requires rapid feedback. Taking a target cost as an example, it is advisable to update the expected cost of the project as often as practical. Figure 8 shows the dashboard—a kind of visual control tool—of a project that used bi-weekly cost updating.

[16] “Making” strategies are developed in parallel with product design. Prefabrication and preassembly details are developed in detailed engineering and installation details are developed nearer in time to installation.

Figure 8: TVD bi-weekly dashboard: Sutter Health Eden Medical Center, Castro Valley, California (Used with permission from Sutter Health)

Most TVD projects have used 3D modeling (BIM) and quantity takeoffs from the model to feed into cost estimate updates. Making this feasible requires a significant amount of team planning early in project delivery, because standards in regards to model detail and completeness at various points of design development (specifically focused on products and processes for which the cost evolution will be tracked) must be established between the owner, designers, builders, and suppliers, and then put into use. Estimating methods must be tuned to the challenge posed by as-yet incomplete models, so will be more conceptual and parametric in nature early on in the design process. Only when models are detailed, can bills of quantities be extracted from them and used with unit costs in order to derive estimates.

All-team meetings (sometimes called Big Room meetings) to review model development and performance against targets are commonly held weekly, especially on larger projects. Cost is not fixed because, like the schedule, it is a forecast. It is dynamic and can and will change (even during construction). Deviations are to be expected. The questions are: Which direction will the deviations head towards? and What is the magnitude of the change (opportunity or risk)? Making information visual and easily available is part of the tool set for designing to targets. The graph in the upper left corner of Figure 8 shows how well the project is steering toward its $320 million target cost. The columns represent different components of the total cost of the project. The colors on the columns represent:

Red: Total project actual cost of work inclusive of escalation estimate and warranty allowance.

Green: Owner's budget (not part of the IFOA contract) inclusive of Owner's contingency.

Orange: IFOA team's contingency.

Blue: IFOA team's shared profit pool.

In the 8 months shown here, the expected cost of the project fell by $30 million without compromising owner value, i.e., the clinical program or vision for model of care. Reduction in expected cost as design becomes more detailed is the opposite of "normal"—an anomaly that demonstrates the power of TVD. The cost of the work for which the IFOA team was directly responsible (red portion of columns) fell even more, by $60 million (from $280 million to $220 million). As total project cost fell to the target cost of $320 million, first contingency (orange) and then profits (blue) were progressively assured.

Cost reduction of that magnitude does not result from doing business as usual. On the contrary, the alignment of interests and clarity of goals promotes innovation in design of product and process, and all manner of waste reduction. The aforementioned anomaly (that expected cost falls as design develops) is testimony to the fact of waste in industry processes and contradicts the widely held belief that the cost of constructed assets is determined once the asset to be constructed is defined.

This project completed in October 2012 with the risk pool member companies getting 80% of their potential profit, which was better than their average profit on conventional projects and earned with less downside risk. (Note: On some projects, the gainsharing zone, and hence the maximum amount of fee the members of the risk pool can achieve, is not limited.)

Other project information depicted in this complex graphic includes sources for cost estimate data, committed costs, cost reduction required to assure maximum profits, and the amount of money spent on pre-construction over time (chart in upper right corner of Figure 8).

3.3.3.2 Promoting the Culture of Collaboration and Innovation

The culture of collaboration and innovation is promoted by means of education, visual information, leadership, and management methods. While people may be quick to say they have been doing TVD (e.g., having participated in cluster group workshops), trust may be lacking among project team members, preventing them from having real conversations about difficult things (esp. with the owner present) as needed to optimize their project as a whole.

3.3.3.2.1 Education

On-boarding processes on TVD/IPD projects now commonly include some type of "lean boot camp" that all project personnel must attend so everyone shares the same knowledge and experience of lean concepts, principles, and methods (e.g., Temecula 2015). Such an on-boarding process would offer training in the TVD process overall as well as training in lean culture and the tools needed to implement it. As mentioned, TVD tools include knowledge of set-based design, multiattribute decisionmaking with CBA, the development of A3s, and Last Planner training with hands-on exercises so team members can experience the impact of unreliability in handoffs and pull planning, and build trust in their own and each other's capabilities.

3.3.3.2.2 Visual Information

In order to develop shared understanding so as to enable informed decisionmaking that aims at optimizing the whole, all project participants must have easy access to up-to-date project data. Work processes must help create transparency and visibility of project status and progress for all involved. For example, TVD status data may be displayed on dashboards (Figure 8) or using other means, such as posters on walls in a Big Room or along corridors.

3.3.3.2.3 Leadership

Leadership includes setting direction. In TVD/IPD projects, the project objectives are shared by all. Keeping those objectives always visible and understood is essential for optimizing the whole, not the part. This requires a new type of project leadership (Seed 2014).

Lean includes leader standard work, which specifies how each supervisor is to develop and improve standardized work, enforce current standards, and develop their people's capability to solve problems and to teach others how to solve problems (Rother 2009, no date). Without leader standard work, even the best uses of lean principles and methods will eventually run out of energy. New energy comes from promoting continuous learning by every person in the organization.

3.3.3.2.4 Management Methods

Lean management methods can be understood as managing by means (as opposed to managing by results) (Johnson & Bröms 2000). Consider the difference between project control and production control. The job of project control is to determine if the project is achieving its objectives. The job of production control is to do what is needed to achieve project objectives. The first is reactive. The second is proactive. Both are needed, but doing only the first is like trying to drive a car while looking in the rear view mirror.

The idea behind managing by means is to provide the conditions needed for success. That is done through TVD, set-based design, Choosing By Advantages, A3 reports, the Last Planner system of production planning and control, leader standard work, making information visual, and more—all of which are methods to promote collaboration, innovation, and continuous learning.

3.3.3.3 Production Planning and Control

The principles and functions of the Last Planner® system (Ballard et al. 2009) are used to plan and control the work. Larger, more complex projects tend to use software to instantiate these principles and functions, and to gain the benefits of data capture for analysis.[17]

The Last Planner system is based on the following principles:

- Plan in greater detail as you get closer to doing the work.
- Produce plans collaboratively with those who will do the work.
- Reveal and remove constraints on planned tasks as a team.
- Make and secure reliable promises.
- Learn from breakdowns.
- Structure the work to achieve smooth work flow.

This first Last Planner principle should not be interpreted to prohibit producing a detailed master schedule at the beginning of a project. How else would one explore risks and alternative strategies and hence make a prudent decision if to pursue schedule milestones? However, a detailed master schedule will be wrong in exactly the way forecasts miss the mark the further into the future they extend, and the greater the level of detail they presume. The sense of the

[17] Ballard (2002) and Ballard et al. (2009) address the applicability of Last Planner to design.

principle is, regardless of the level of detailed schedule previously produced, that teams must rethink the work plan and schedule as the project unfolds, phase by phase, with those who will actually perform the work of each phase.

Last Planner is a complex lean tool that uses various methods for performing its different functions (Table 3).

Table 3: Functions and methods of the Last Planner system

Functions	Methods
A. Detailing the phases between master schedule milestones	A. Pull planning and designing the work for flow
B. Making tasks ready in lookahead planning	B. Constraints analysis and removal B. Task breakdown B. Operations design
C. Selecting tasks for daily and weekly work plans	C. Commit only to tasks that are well defined, sound, in proper sequence, and sized to the capability of performers
D. Making handoffs reliable	D. Reliable promising
E. Measuring planning system performance	E. Percent Plan Complete (PPC) E. Tasks Made Ready (TMR) E. Tasks Anticipated (TA) E. Repetitive Errors Avoided
F. Learning from plan failures	F. Five WHYs

3.4 Steering Construction to Targets

Creativity in the design of product and process, coupled with disciplined execution, alert for learning opportunities, is the hallmark of target value delivery. Naturally the design phase attacks product design, but process design also starts in the design phase of TVD projects.

Once construction starts, process design continues at more granular levels. Universal Health Services, Inc. (UHS)’ Temecula Valley Hospital project was one of the most advanced in steering construction to targets (Do et al. 2015). Following are some examples drawn from that project. Figure 9 and Figure 10 illustrate the project’s investment in the use of prefabrication and preassembly.

Figure 9: Prefabricated Exterior Wall Panels[18]

Figure 10: Prefabricated roof truss

18 All figures are courtesy of UHS.

Figure 11 shows the kind of analysis that was done on construction operations. Administrative processes were also included: Figure 12 illustrates that the team invested in making processes such as submittals visual and easily understandable.

Figure 11: Design of door installations

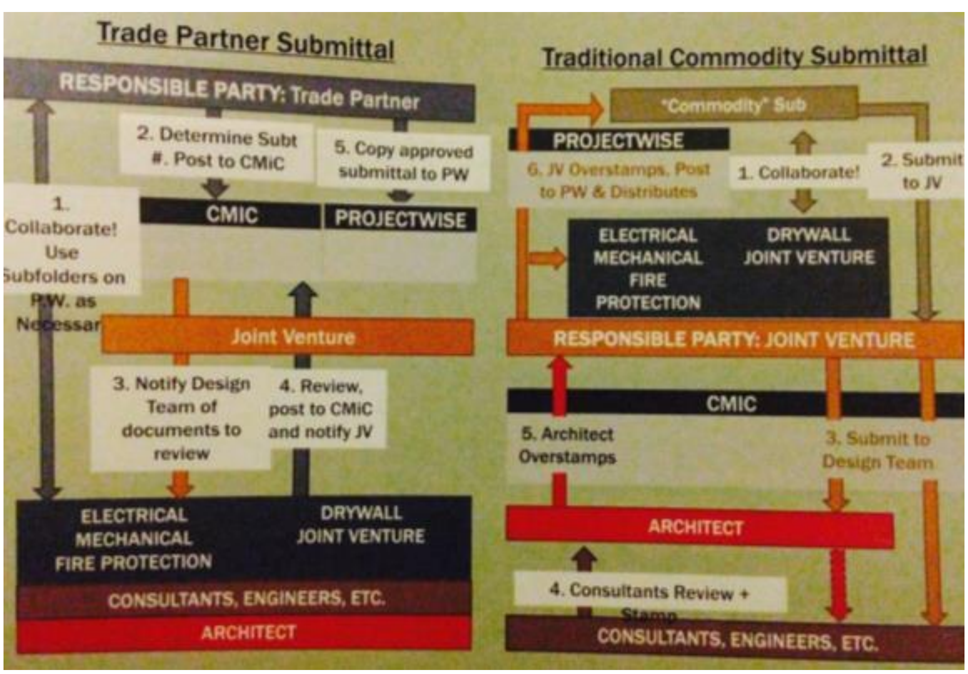


Figure 12: Process map for submittals

Dry erase boards like that shown in Figure 13 were placed on all floors of the building during its construction, to allow and encourage sharing problems, suggestions, and news.

Figure 13: Dry erase boards on all floors

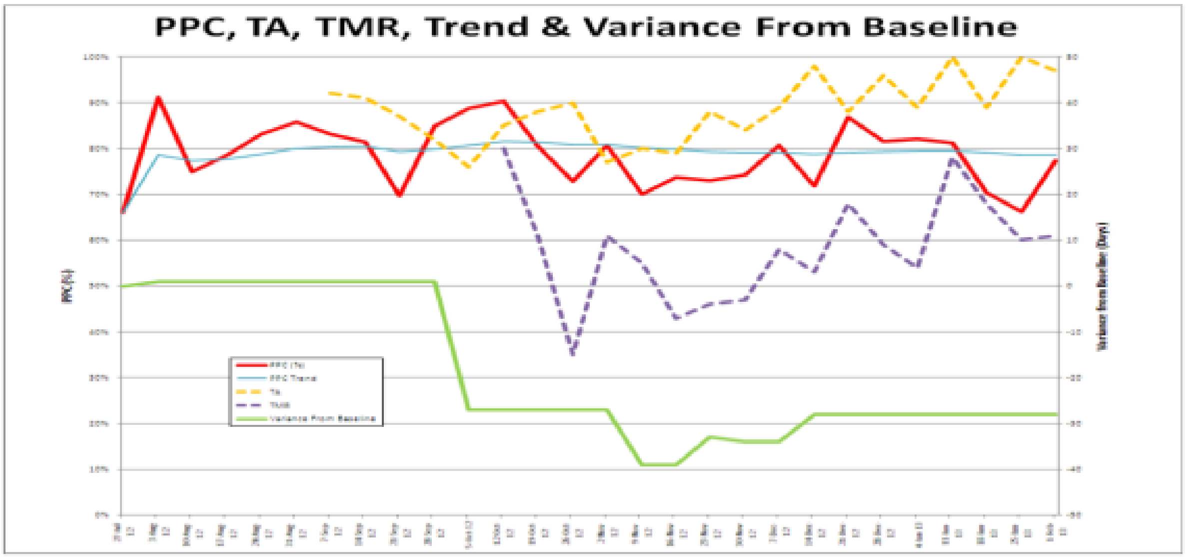


Figure 14: Last Planner metrics

The Last Planner system was used throughout the project for production planning and control. Figure 14 shows PPC by week in red and the trend line in blue. The project averaged about 80% PPC.

Also shown are two additional Last Planner metrics: **Tasks Anticipated (TA)** in yellow and **Tasks Made Ready (TMR)** in purple. TA is driven by how well tasks are broken down into operations and those operations are designed. TMR is driven by constraints analysis and the discipline of committing only to tasks that are well defined for craft workers, sound as regards constraints, in proper sequence, and sized to the capabilities of those doing the work. TA rose to above 90% and TMR near 80%; both of which are substantially better than previous measurements.

The last bit of information on the chart is the Variance from Baseline in green: the number of days behind (above "0") or ahead (below "0") of schedule. When this chart was published, the project was about 28 days ahead of schedule.

Figure 15: Monthly Update on Temecula Valley Hospital for December 2012

Steering to targets requires frequent comparison of actual vs. target. Along with continuation of the comparison of actual cost to target cost, the project also tracked productivity and its impact on manpower curves, which obviously drive labor cost. Monthly updates kept everyone aware of where they were against where they wanted to be, while encouraging innovation and improvement. Quite clearly, innovation in process design and engaging those doing the work to make it better was a huge part of Temecula Valley Hospital's success. One indicator of that success is the cost per square foot of the hospital. Figure 16 shows that the average for California hospitals was $680/ft^2 at the time. The project's target was $500/ft^2 and their cost at completion was $480/ft^2.

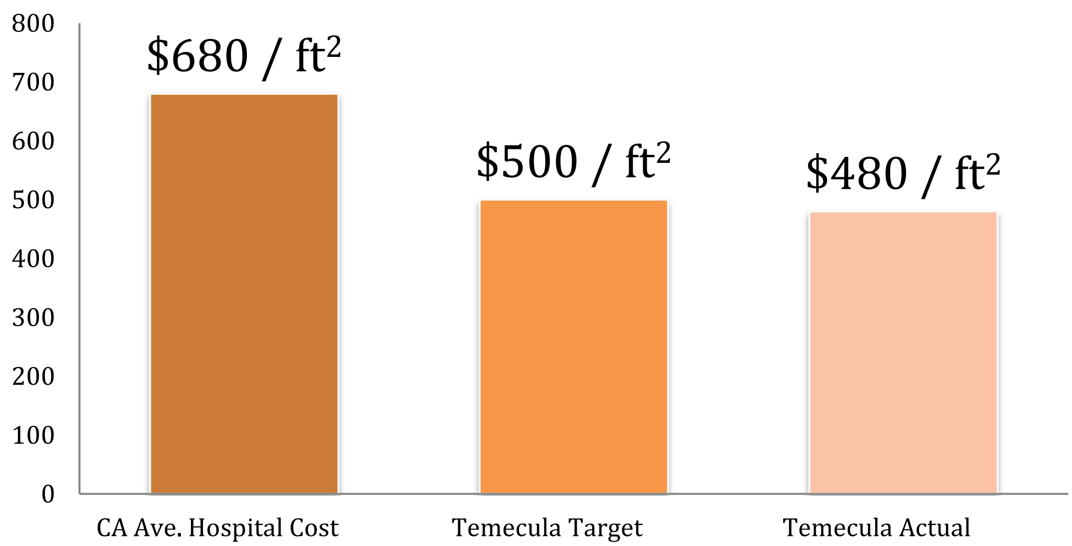


Figure 16: Hospital cost per square foot, (left) Average in California, (middle) Temecula Target, and (right) Temecula Actual

4 Getting Started

4.1 Current Benchmark for Target Value Design

How best to do Target Value Design? Ballard's current benchmark (published in 2011 and reprinted here) recommends the following, but note that research to date has been limited to healthcare and educational facilities, working with owners acquiring means of production for their own use. The TVD process may require changes when applied to other owner and facility types.

1. With the help of key service providers, the customer develops and evaluates the project business case and decides whether to fund a feasibility study; in part based on the gap between the project's allowable and market cost.
2. The business case is based on a forecast of facility life cycle costs and benefits, preferably derived from an operations model; and includes specification of an allowable cost—what the customer is able and willing to pay to get life cycle benefits. Financing constraints are specified in the business case; limitations on the customer's ability to fund the investment required to obtain life cycle benefits.
3. The feasibility study involves all key members (designers, constructors, and customer stakeholders) of the team that will deliver the project if the study findings are positive.
4. Feasibility is assessed through aligning ends (what's wanted), means (conceptual design), and constraints (cost, time, location, …). The project proceeds to funding only if alignment is achieved, or is judged achievable during the course of the project.
5. The feasibility study produces a detailed budget and schedule aligned with scope and quality requirements.
6. The customer is an active and permanent member of the project delivery team.
7. All team members understand the business case and stakeholder values.
8. Some form of relational contract is used to align the interests of project team members with project objectives.
9. A cardinal rule is agreed upon by project team members – cost and schedule targets cannot be exceeded, and only the customer can change target scope, quality, cost, or schedule.
10. The cost-, schedule-, and quality implications of design alternatives are discussed by team members (and external stakeholders when appropriate) prior to major investments of design time.
11. Cost estimating and budgeting are done continuously through intimate collaboration between members of the project team, what we call "over the shoulder estimating."
12. The Last Planner system is used to coordinate the actions of team members.
13. Targets are set as stretch goals to spur innovation.
14. Target scope and cost are allocated to cross-functional TVD teams, typically by facility system (e.g., structural, mechanical, electrical, exterior, interiors).

15. TVD teams update their cost estimates and basis of estimate (scope) frequently. Example from a major hospital project during the period when TVD teams were heavily in design: estimate updates at most every three weeks.
16. Stakeholders have a stake in the project; its outcome affects their interests; e.g., permitting agencies, neighborhood representatives, facility users, investors.
17. The project cost estimate is updated frequently to reflect TVD team updates. This could be a plus/minus report with consolidated reports at greater intervals. Often project cost estimates are updated and reviewed in weekly meetings of TVD team coordinators and discipline leads, open to all project team members.
18. Co-location is strongly advised, at least when teams are newly formed. Co-location need not be permanent; team meetings can be held weekly or more frequently.

To implement these components of the current benchmark involves a radical change from traditional practice. Consider the following:

- Customers spend more time and money in the project definition phase of projects than they traditionally have done (knowing this will pay off later in project delivery).
- Key members of the project team are selected through value based proposals rather than competitive bidding.
- Architects relinquish their exclusive access to customers.
- Design professionals embrace true collaboration with suppliers and builders – collectively exploring problems and jointly developing solutions.
- Suppliers and builders understand and respect designers and learn how to contribute and participate in project definition and design processes.
- Design solutions are developed with cost, schedule, and constructability as design criteria.
- Designers' work is restructured based upon completing smaller batches of design documents and releasing work to other members of the team.
- General contractors allow and encourage specialty contractors to have an equal seat at the table.
- The incentives of all team members are aligned with pursuit of project objectives.

To successfully make these changes requires special effort. The following have been observed to be effective:

1. Clear understanding and frequent reminders of customer value.
2. Clear statements up front, plus frequent reminders, about the nature and extent of the changes required in attitudes and behaviors.
3. Standard processes to encourage collaboration and measure progress toward targets.
4. Inclusion of all team members in user group meetings and other occasions where they can hear and see for themselves what is of value to the customer and other stakeholders.
5. Empowering and requiring team members to declare breakdowns; i.e., to speak up when they perceive that agreed criteria are not being followed, that value is being sacrificed or waste is being generated.
6. Education, coaching, and building trust among team members.

Specific tools and techniques used to do the work of planning and designing include:

- Space planning based on contents and use, not historical standards.
- Reverse phase scheduling (aka, pull scheduling, pull planning).
- Fixed schedules for user group meetings.
- Room data sheets as records of agreements, signed off by users.
- Weekly coordinating meetings with strict documentation of commitments.
- nD computer models (aka BIM).

1.2 Going beyond the Current Benchmark to Better Practice

The current benchmark may be used to guide a new implementation of TVD or to compare the extent of TVD use on different projects (e.g., Denerolle 2011). However, we do not believe that the current benchmark is the best that can be achieved. Indeed, given the lean principle of continuous improvement, better practice is always possible. Based on research to date, we offer the following tasks to be performed and hypotheses to be explored and experimentally tested:

- How best to select project delivery teams; e.g., test for compatibility, engage self-assembled teams, other?
- Can the process of determining stakeholder value be improved, be done earlier? Can stakeholder management be improved? Can the number of stakeholders be reduced?

- How best size and manage contingency to achieve targets? Research to date suggests that contingency reduction is one of the primary contributors to underrunning market costs, but the nature and extent of contingencies is not sufficiently understood.
- What information technologies can be used (and how) to support Target Value Design practices; e.g., integrating product, process and cost models?
- What training is needed to support TVD; e.g., training in consensus decision making?
- Development of TVD began with owners of healthcare and education facilities building means of production for their own use. How/Can TVD be extended to other owner types, construction sectors and situations?
- Analyze and explain phenomena associated with TVD:
    - On TVD projects to date, the expected cost (cost estimate) has declined as design has developed. Initial analysis suggests that this is caused by proactive value engineering, increased scope control, refinement of scope to reflect buildability and other design criteria, and reduction of contingency in estimates.
    - TVD projects to date have been completed under market (as much as 19% under) and under budget (client's allowable cost). How explain? Can this be reliably repeated?
    - Does the investment in upstream processes pay off in (a) the avoided costs of bad projects that are not allowed to continue, (b) in the increase in value from more effective processes for articulating values and controlling design and construction to the delivery of those values, (c) in the reduction in waste from incomplete and inaccurate drawings, from duplicated efforts, from rework, (d) from more reliable delivery to quality, time and cost expectations, (e) from the ability to respond more quickly to changes and discoveries?
- Describe and assess practices used in previous TVD implementations:
    - Industry advisors' role in client project business planning.
    - Benchmarking against market cost. Both the "Quarterback Rating" process developed by Scott Morton of Boldt (Morton 2008) and Haahtela's TaKu process (Pennanen and Ballard 2008, Ballard & Pennanen 2013) look promising, but need testing.
    - Aligning team member interests.
    - Populating cost models as early as possible with quantities and rates.
    - Proactive value engineering/value management.

- Set-based design strategy, so that selection from design alternatives is made at the last responsible moment and all time and resources available within project constraints are used to test and develop alternatives.
- A3 format for proposals.
- Choosing by Advantages to select from design alternatives.

- Motivated by a desire to be able to invest cost savings earlier in projects, P2SL has launched an initiative to develop and test a '"Whole Life Target Value Design," involving the following steps:
  - Learn how to derive an allowable cost from a facility operations model.
  - Learn how to link facility models (BIM) to facility operations models, so the impact of design alternatives on whole life costs and benefits can be predicted.
  - Give facility operations models to the project team so they can recalculate the allowable cost based on expected impact of design alternatives on whole life costs and benefits.
  - Learn how to finance projects where the budget (allowable cost) varies during design, and where whole life investment decisions are made during design.

To participate in the Target Value Design research initiative please contact Glenn Ballard, P2SL Director or Research, at ballard@ce.berkeley.edu or (415) 710-5531.

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7 Glossary

Words in **bold** refer to concepts that were introduced in the document.

allowable cost (AC): What an owner is willing and able to pay in order to get what they want, in other words, what that product or asset is worth to them.

Big Room (Oba, Obeeya): Physical space where multidisciplinary specialists can meet to share incomplete information often, to collaborate and to maintain a visual work place.

BIM → see Building Information Model(-ing).

Building Information Model(-ing) (BIM): Integrated database system, one output of which is a 3-dimensional model. 3D BIM refers to the 3-dimensional geometrical model, 4D also includes time, 5D further includes cost, and 6D BIM refers to a BIM annotated with data to support facility life-cycle management.

CBA → see Choosing by Advantages

Choosing by Advantages (CBA): System for sound decisionmaking formalized by Jim Suhr (1999).

conditions of satisfaction (COS): Directives (proactive: for steering) and **criteria** or **constraints** (reactive: for judging), imposed by the entity initiating a process (usually the owner) that specify how success of the outcome will be gauged.

constraint: Something that stands in the way of a task being executable or sound. Typical constraints on design tasks are inputs from others, clarity of requirements criteria for what is to be produced or provided, approvals or releases, and labor or equipment resources. Typical constraints on construction tasks are the completion of design or prerequisite work; availability of materials, information, and directives. Screening tasks for readiness is assessing the status of their constraints. Removing constraints is making a task ready to be assigned.

cost modeling: The practice of keeping track of component- and system costs in the course of design, as may be done using a 5D BIM.

design: A type of goal-directed, reductive (not deductive) reasoning. There are always many possible designs, especially if one is willing to relax constraints (requirements). Product design reasons from function to form. Process design reasons from ends to means.

EC → see Expected Cost

Expected Cost (EC): Estimate of what you will have to pay for something desired at some point in the future.

first-run study (FRS): First trial execution of an operation as a test of capability to meet safety, quality, time and cost targets. The FRS begins 2-3 weeks ahead of the first run with a planning session in which the team that will do that work is involved in developing a detailed work plan at the 'step' level of task breakdown, so each person on the team knows what they are to do. First run studies follow the plan-do-check-act cycle. The plan is developed, the first run is carried out, the results are checked against the targets. If the results are inadequate, the operation design is replanned and the test performed again. This continues until the operation is considered capable, then that way of doing that type of work is declared the standard to meet or beat. First-run studies are done ahead of the scheduled first start of the operation, while there is time to acquire different or additional prerequisites and resources. First run studies are one of three ways in which operations can be designed: the other two are virtual prototyping (VFRS) and physical prototyping (mock ups).

Integrated Project Delivery™ (IPD): A delivery system that seeks to align interests, objectives and practices, even in a single business, through a team-based approach. The team primary Team Members would include the Architect, key technical consultants as well as a general contractor and key subcontractors, thereby creating an organization able to apply the principles and practices of the Lean Project Delivery System. They may sign a multi-party contract.

Last Planner® System (LPS): System for project production planning and control, aimed at creating a work flow that achieves reliable execution, developed by Ballard (2000).

Last Responsible Moment (LRM): While considering alternatives, the last responsible moment for one alternative is the time at which, if that alternative is not selected and pursued, that alternative is no longer viable. → used in **Set-Based Design**

LPS → see Last Planner System

LRM → see Last Responsible Moment

Market Cost (MC): What an owner may expect to pay for a desired asset-based on comparison to historical market cost for similar assets. Hence, it is the initial expected cost determined through benchmarking to market of the owner's wants. The comparison to allowable cost determines whether or not to proceed with validation. It comes into play in business planning or in the course of the budget validation.

Oba, Obeeya: → see Big Room

Percent Plan Complete (PPC): The number of planned completions divided into the number of actual completions, usually referring to tasks in a **commitment plan**. (LCI website 2009-09-15 under PPC)

Plus/Delta: A discussion at the end of an activity, meeting, or project used to evaluate and learn from its performance by capturing: (1) Plusses: What worked or produced value during the session? and (2) Deltas: What could we do differently or better next time to improve the process or outcome?

Point-Based Design (PBD): A design methodology whereby one (or a few alternative) solutions to parts of the problem may be explored, one gets selected, and that one is then passed on to the next design specialist.

PPC → see Percent Plan Complete

SBD → see Set-Based Design

Set-Based Design (SBD): A design method whereby sets of alternative solutions to parts of the problem are maintained until their **Last Responsible Moment**(s), in order to find by means of set intersection the best combination that solves the problem as a whole.

Target Cost (TC): The cost that a project team is striving to achieve, either less than or equal to the allowable cost, and typically a stretch goal relative to previous performance capability. Note that the project target may be set in terms of scope: to deliver more value for a given cost.

target costing: A method used by consumer and industrial product manufacturers to manage product profitability (Cooper & Slagmulder 1997 and 1999). After defining the functionalities of a new product and conducting market studies, the manufacturer estimates the revenues they will receive from sales, subtracts the profit they consider acceptable, and the remainder is the target cost—the most money they can spend on designing, manufacturing, servicing, and disposing of the product and still make their target profit.

Target Value Design (TVD): The practice of defining scope, performance goals, and a target cost in advance of starting design, and then steering the design process so as to meet all. TVD may also be read as Target Value Delivery or Whole Life Target Value Design to amplify the pursuit of TVD while taking into account not only Design, Construction, Operations and Maintenance, and Decommissioning, but also Business Costs and Outcomes.

Tasks Anticipated (TA): A metric in the **Last Planner System** that gauges the percentage of all tasks in a plan for a target week that were anticipated in an earlier plan for that target week. Together with **TMR** it characterizes the ability of the planning team to make work ready.

Tasks Made Ready (TMR): Metric in the **Last Planner System** that gauges the ability of the plan(ner) to forecast (predict) accurately in week i what tasks will take place j-i weeks into the future (TMR_{ij}). It gauges the percentage of tasks in an earlier plan for a target week that are included in a later plan for the target week. Together with **TA** it characterizes the ability of the planning team to make work ready.

TVD → see Target Value Design

(of) value: Something is “of value” to someone when it is appreciated by them. This may be expressed by saying Thank You, willingness to pay for it, offering something non-monetary in return, etc.

→ as opposed to **values**

values: Behavioral principles, rules for how people should behave. Expressed as **conditions of satisfaction** or **constraint**s on the selection of ends and means.

→ as opposed to **value**

Virtual First Run Study (VFRS): Virtual prototyping effort conducted well in advance of the execution of the work being studied, in order to learn how it can be done in the best possible way.

virtual prototyping: Developing models in a computer system, such as a **BIM**, to study the design and production of a product or process.

Whole Life Target Value Delivery → see Target Value Design

worth: assessment of costs and benefits from use of the asset to be constructed (asset worth)