Technical Report

The application of Target Value Design to the design phase of 3 hospital projects

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1 Introduction

Target Value Design (TVD) is a management practice that drives design to deliver customer values, and develops design within project constraints (Ballard, 2009a). It is the primary management method for lean definition and design. This research initiative is a 3-year effort that was launched in June 2010 by DPR Construction. The stated objectives of this research project are:

1. Improve the target value design (TVD) process when applied in Lean/IPD projects.
2. Adapt the target value design process to other applications; e.g., proposal and bid development, design-build projects.

This Technical Report covers the design phases of the three case study projects. A subsequent report will be issued on their construction phases.

We are following the value stream mapping methodology, first producing a current state map of the TVD process, identifying and agreeing opportunities for improvement and/or adaptation to other applications, producing a future state process map(s), planning how to create the desired future state process, then implementing those action plans, evaluating the results, and finally revising the future state process and action plans, if not yet satisfied, or deploying the new process(es). As of June 2011, the research team has produced a current state map and identified opportunities for improvement. This technical report presents the findings to date, by describing and evaluating the TVD processes implemented on 3 case studies, whose characteristics are presented in table 1.

Table 1: Case studies characteristics

	Sutter Medical Center at Castro Valley	Alta Bates Summit Medical Center Patient Care Pavilion	UCSF Medical Center at Mission Bay
Total Project Cost	$309,000,000	$298,894,237	$1,500,000,000
Projected EMP/GMP	$233,121,735	$243,883,391	$765,470,000
Square Footage	231,966	233,050	869,000
Number of Beds	130	240	289
Collaboration level	IPD	IPD	IPD-ish

These 3 projects are different in nature (size, contractual agreement, affiliates…), and the achievements, challenges and issues identified vary from one project to another. Consequently, the implementation of TVD on these 3 projects won't be compared to one another, but rather to an academic baseline. After introducing the history of TVD methodology development, this report successively presents how the TVD implementation on each case study relates to the TVD benchmark. Finally, the last section summarizes the issues and opportunities for improvement that were pointed out on these 3 projects.

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2 History of TVD methodology development

2.1 Integrated Project Delivery (IPD) and Target Value Design (TVD)

The terms IPD and TVD might be a source of confusion. IPD is a delivery approach, while TVD really is a management practice. AIA defines IPD as "a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction" (AIA, 2007). All project delivery systems have three basic domains within which they operate: the project organization, the project's "operating system," and the commercial terms binding the project participants (Thomsen et al., 2009), which is illustrated in this triangle model (cf. figure 1).

Figure 1: The LCI triangle model (Thomsen et al., 2009)

The structure in each of these 3 domains is equally important and needs to be aligned in order for the delivery system to be coherent. TVD is a design strategy and process that drives design to deliver customer values within project constraints. The term might seem overly simplistic, but TVD is a Lean "tool", which therefore belongs to the bottom part of the triangle: the project "operating system". This triangle model stresses the fact that one face of the triangle cannot go without the others. Therefore, this report also addresses the project organization and the commercial terms and their influence on the TVD process.

2.2 Historical perspective

Target costing was developed as a method of controlling product profitability in the product development processes of primarily Japanese manufacturers. Target Value Design (TVD) names the adaptation of target costing from product development to construction. The first publication on target costing in construction was by Nicolini et al. (2000). That paper described a failed attempt by the U.K. Ministry of Defense to apply target costing on two military housing projects. The failure was said to be based in the U.K. contractors inability to manage cost, having become habituated to buying, rather than designing and making.

The first successful target costing application in construction was the Tostrud Fieldhouse Project at St. Olaf's College in Northfield, Minnesota, led by the general contractor, Boldt Construction, and completed in 2002 (Ballard and Reiser, 2004). Many features of current practice were anticipated, including:

- A target cost that could only be increased by the owner.
- Value-based selection of key design and construction firms, including architect, general contractor, structural engineer, mechanical engineer, electrical engineer, mechanical contractor, and electrical contractor.
- Allocation of the total target cost to cross functional teams organized by building system
- Money was able to move across contractual and organizational boundaries; e.g., the civil team overran its target cost, but mechanical and electrical underran theirs, keeping the total cost within the project target.
- Final cost was within the target, releasing funds for investment in value additions to the facility.
- Final cost was substantially below the market benchmark; 2/3 the square foot cost of a similar facility in the same city.

Boldt continued its application of target costing on a number of projects after Tostrud, including the Shawano Clinic Project for Thedacare, which was completed 17% under the market benchmark in 2005.

In 2005, Sutter Health initiated a series of target costing projects, working with the University of California's Project Production Systems Laboratory. Their first project was the Acute Rehabilitation Center (ARC) at Sutter Roseville Medical Center. Three previous projects on the same campus with the same team members had resulted in multiple returns to the Sutter Health Board of Directors for additional funding. ARC was completed within its initial budget in a period of rapid cost escalation for materials, reversing the previous trend.

The name "target value design" first appeared in a paper by Hal Macomber, Gregory Howell and Jack Barberio (Macomber et al., 2007), introduced to emphasize that construction project targets were not limited to cost and that delivery of value to customers was paramount. Subsequently, the name was adopted by Boldt and Sutter Health, and was accepted by the U.S. construction industry.

Sutter Health and Boldt's experiments in Target Value Design merged in Sutter's Fairfield Medical Office Building Project, which was completed in 2006 with Boldt as Construction Manager/General Contractor for 19% below the market benchmark. This was also the first relational contract used on a Sutter Health project. Its Integrated Form of Agreement was developed for the Lean Construction Institute and for Sutter Health by William Lichtig, then of McDonough, Holland & Allen in Sacramento, CA.[1]

Subsequent to these successes, other U.S. healthcare companies adopted Target Value Design, with successful projects completed by SSM (St. Louis), Unified Health Services, University of California at San Francisco, and others.

The Project Production Systems Laboratory published a process benchmark for Target Value Design in 2005 and a revision of that process benchmark in 2009. These process benchmarks are used in this study as the basis for comparison of the practices observed in the three TVD hospital projects on which DPR Construction was the Construction Manager/General Contractor.

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[1] This combination of Target Value Design with a relational contract led the Project Production Systems Laboratory and the Lean Construction Institute to develop the model/hypothesis that optimum project performance requires the alignment of interests in commercial terms, integration into the project organization of all key players from the start, and lean management as the project operating system. See also Thomsen et al., 2009.

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2.3 Presentation of the TVD Benchmark

The University of California, Berkeley's Project Production Systems Laboratory periodically publishes a description of the current benchmark in each project management process that is a subject of research. On July 26, 2009, Glenn Ballard (2009b) published a report on the current benchmark in Target Value Design (TVD), which is presented here:

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, etc.). 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[2].
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 is done continuously through intimate collaboration between members of the project team—'over the shoulder estimating'.
12. The Last Planner®[3] 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. 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

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[2] Stakeholders have a stake in the project; its outcome affects their interests; e.g., permitting agencies, neighborhood representatives, facility users, investors.

[3] Last Planner is a registered trademark of the Lean Construction Institute.

are updated and reviewed in weekly meetings of TVD team coordinators and discipline leads, open to all project team members.

17. 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.
- 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.

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. The three case studies presented in this report will help assessing the strengths and limitations of the current TVD benchmark. The opportunities for improvement identified in section 7 will be the basis for exploration and experiments for a new TVD practice.

3 Research methodology

3.1 Value Stream Mapping approach

The Value Stream Mapping (VSM) approach has been followed for this research:

1. Map the current state;
2. Identify opportunities for improvement;
3. Map the future state;
4. Develop and implement action plans;
5. Measure & revise.

As of today, steps 1 and 2 have been completed and the research team is currently working on the future state map. A value stream map is a comprehensive model of the project that reveals issues hidden in current approaches (Howell and Ballard, 1998). Therefore, the current state map presented in this report is a collection of flow charts and corresponding narratives to describe the implementation of TVD on the 3 case studies.

3.2 Information sources

3.2.1 Interviews

Most of this report narrative is based on qualitative data, retrieved from approximately 30 interviews (ranging from 45 to 75 minutes). As represented in table 2, principals and project managers of the project teams were questioned—several times for some of them—over the first year of this research initiative. The interviews were recorded and transcribed verbatim to facilitate analysis later on.

Table 2: Interviewees on the 3 case studies

		SMCCV	ABSMC	UCSF
	Owner	D. Christian	J. Gomez	
A/E	**Architect**	J. Mobley	R. Jaramillo	A. Killeen, L. Harrison
A/E	**Structural Eng.**	M. Aliaari	J. Love	R. Daswani
A/E	**MEP Eng.**	B. Johnson, K. Martin	S. Ainsworth	R. Daswani
CONTRACTORS	**GC (DPR)**	E. O'Neill, T. Findley	H. Yap, S. Eldridge	J. Poindexter, D. Saripally
CONTRACTORS	**Mechanical**	B. Huey	Z. Sargent	T. Smith
CONTRACTORS	**Electrical**	L. Slagle		M. Potter
CONTRACTORS	**Plumbing**	T. McClenahan	T. McClenahan	
CONTRACTORS	**Exterior Skin**		D. Ryor	

Although parties from each side have been involved (Owner, A/E, Contractors), it must be noted that this research effort was initiated by DPR. As a result, some of the considerations presented in this report might be a little more relevant to the contractors' side. In the future, extra effort will be devoted to encompass every facets of the TVD process and include more input from owners, for instance.

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3.2.2 Survey

Key actors from the 3 projects were invited to fill out a web-based survey aimed at assessing how well the TVD benchmark had been implemented on the 3 case studies. The respondents had to rate each component of the benchmark on a 5-point scale.

Table 3: Results from a survey conducted to rate the implementation of the TVD benchmark

Components of the current TVD benchmark (rated on a scale of 0 to 5)	SMCCV		ABSMC		UCSF	
	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.
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.	**4.1**	0.8	**3.4**	1.3	**2.3**	1.7
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.	**3.2**	1.3	**3.4**	1.1	**2.5**	1.5
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.	**4.8**	0.5	**3.9**	0.9	**2.7**	1.8
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.	**4.7**	0.5	**3.9**	0.9	**3.2**	1.9
5. The feasibility study produces a detailed budget and schedule aligned with scope and quality requirements.	**4.4**	0.5	**4.1**	0.7	**2.8**	1.3
6. The customer is an active and permanent member of the project delivery team.	**4.8**	0.4	**3.7**	1.1	**4.2**	1.3
7. All team members understand the business case and stakeholder values.	**3.5**	0.9	**3.0**	1.0	**3.3**	1.4
8. Some form of relational contract is used to align the interests of project team members with project objectives.	**4.8**	0.4	**4.7**	0.5	**2.3**	1.7
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.	**4.5**	0.7	**3.9**	0.7	**4.0**	0.9
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.	**3.9**	0.7	**3.1**	0.9	**3.7**	1.2
11. Cost estimating and budgeting is done continuously through intimate collaboration between members of the project team—'over the shoulder estimating'.	**4.1**	0.7	**3.1**	0.7	**3.8**	1.3
12. The Last Planner® system is used to coordinate the actions of team members.	**3.8**	1.8	**3.9**	0.7	**3.9**	1.1
13. Targets are set as stretch goals to spur innovation.	**4.2**	0.9	**3.6**	1.0	**3.8**	1.3
14. Target scope and cost are allocated to cross-functional TVD teams, typically by facility system; e.g., structural, mechanical, electrical, exterior, interiors, …	**4.4**	0.7	**4.3**	0.8	**4.3**	0.8
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.	**4.1**	0.7	**3.7**	0.8	**3.3**	1.3
16. 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.	**4.5**	0.5	**4.0**	0.6	**4.0**	1.4
17. 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.	**4.5**	0.5	**4.3**	1.1	**4.6**	0.5
TVD SCORE (%)	85%		75%		69%	

The 30 responses—12 for SMCCV, 7 for ABMSC and 11 for UCSF—are presented in table 3, which displays the mean and standard deviation for each component. When the standard deviation is less or equal to 1, meaning that the scores tend to be relatively close to the mean, the corresponding mean is underlined. An overall “TVD score” was calculated by summing the respective mean values and scaling the total to a 0-100% scale.

These results help assessing how the TVD application was perceived on the 3 projects, and will be used later in the report to support some points and arguments. As general comments, SMCCV received the highest “TVD score” (85%), followed by ABSMC (75%) and UCSF (69%). UCSF’s score is surprisingly close to ABSMC’s score, even though this is a non-IPD project. It is also interesting to point out that the respondents’ scores on UCSF are much more spread out than on the other 2 projects. Only 3 components (out of 17) on UCSF have a standard deviation less or equal to 1 (the corresponding mean is underlined in that case), compared to respectively 15 and 13 on SMCCV and ABSMC. This conveys some lack of consensus on UCSF regarding the success of TVD implementation.

3.2.3 Other sources

Additionally, the review of project documents was an important source of information:

- Contractual documents;
- Validation study reports;
- Schedules;
- Budget reports (cluster history, master budget, risk & opportunity log, etc.);
- A3’s;
- Process maps.

Accessing those documents was more challenging on UCSF (especially for budget reports), because of confidentiality issues.

3.3 Analytical framework

The analytical framework presented in table 4 is used in this report for analyzing the implementation of TVD on the 3 case studies. This matrix presents the areas investigated to capture the current state of TVD implementation on the 3 case studies and to identify opportunities for improvement. “Organizing” refers to the commercial terms, the team integration, and everything that was done for allowing TVD implementation. Then, what the team did to “define” the targets is captured in the “Defining” part. Finally, “Steering” refers to the means by which the team steered the design to targets.

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Table 4: Analytical framework matrix

		Key concepts	TVD benchmark practices
Organizing (Preparing mechanisms for...)	**Commercial terms & interests alignment**	· Contractual agreement · Incentives, accountability	· Some form of relational contract is used to align the interests of project team members with project objectives.
	Integrated teams	· Timing of the team partners involvement · Owner's participation · Co-location	· 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. · The customer is an active and permanent member of the project delivery team. · 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.
	Integrated governance	· Core Group · Captains, senior leadership	
	Joint responsibility, transparency	· Team spirit · Trust building · Open book environment	· 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.
	Functional interface	· Training · Shared understanding · Work structuring	
Defining (ends & constraints)	**Business case**	· Access to owner's business case · Whole life cost	· 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. · 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. · All team members understand the business case and stakeholder values.
	Stakeholder values	· Definition and measurement of value · Link value directly to design components · Scope changes	· All team members understand the business case and stakeholder values.
	Plan validation	· Validation study process · Level of details	· 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.
	Target setting	· How are the targets set? · Linkage to business case	· Targets are set as stretch goals to spur innovation.
Steering (Means)	**Cross-functional teams**	· Clusters · Collaboration	· Target scope and cost are allocated to cross-functional TVD teams, typically by facility system; e.g., structural, mechanical, electrical, exterior, interiors, …
	Design planning	· OSHPD submittals · Pull scheduling · Last Planner System®	· The Last Planner® system is used to coordinate the actions of team members.
	Cost modeling	· BIM · Cost estimating · Budget reporting	· The feasibility study produces a detailed budget and schedule aligned with scope and quality requirements. · Cost estimating and budgeting is done continuously through intimate collaboration between members of the project team—'over the shoulder estimating'. · 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. · 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.
	Analysis of alternatives	· Set-based design · Value engineering · PMI and Risk & Opportunity · A3, selection methodology	· 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.

4 Sutter Medical Center at Castro Valley

4.1 Project background

4.1.1 The product

The Sutter Medical Center at Castro Valley (SMCCV) is a $320 million, six-story, 130-bed hospital, which will replace the current Eden Medical Center in Castro Valley, California (Khemlani, 2009). In addition to the construction of the new hospital building, the project also includes campus improvements such as an additional parking and the demolition of the old hospital.

Figure 2: The construction of the new hospital, as of June 2, 2011[4]

The need for a new hospital arose from California's hospital seismic safety law, SB 1953[5], passed in 1994, that requires every hospital in the state to meet specific criteria that would keep these structures standing and provide uninterrupted care if they were struck by a major earthquake. The deadline for complying with SB 1953 is by 2013. Under the stringent earthquake safety requirements, the original hospital building built in 1954 would not be eligible to be licensed as an acute care hospital after January 1, 2013. The hospital management and Sutter Health took advantage of this opportunity to not only build a safe and secure structure, but also an innovative, state-of-the-art hospital in order to deliver a new kind of health care.

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[4] Retrieved from the project blog at: http://suttermedicalcentercastrovalley.org/ (06/02/2011)

[5] SB 1953 was introduced and signed into law in 1994, amending and extending the Alfred E. Alquist Hospital Seismic Safety Act of 1983 (Alquist Act). "The Alquist Act establishes a seismic safety building standards program under OSHPD's jurisdiction for hospitals built on or after March 7, 1973. The Alquist Act was initiated because of the loss of life incurred due to the collapse of hospitals during the Sylmar earthquake of 1971. The Alquist Act emphasizes that essential facilities such as hospitals should remain operational after an earthquake (OSHPD, 2011).

4.1.2 Different actors

Sutter Health is a large non-profit healthcare provider in Northern California. As a result of SB 1953, Sutter Health was forced to undertake seismic improvements on many of its facilities, requiring its organization to execute several large projects in a short period of time (Khemlani, 2009). This motivated Sutter to find ways to reduce the time delays and budget over-runs that are typical of large projects and to position themselves as "the owner of choice" in the industry. Hence, Sutter looked at ways by which the design and construction delivery model could be transformed, and IPD emerged as a viable alternative to the traditional delivery model. And Target Value Design inherently fitted in this context as a key design strategy to better address the needs of Sutter while containing the cost of those facilities.

To identify the participants of its SMCCV project delivery team, Sutter invited selected companies to participate in a co-opetition effort, a neologism used to describe cooperative competition. Sutter's aim was to leverage learning within and across multi-skilled teams. The three teams who participated in Sutter's co-opetition were to compete for the best design of a fictitious hospital, but collaborate at the same time by sharing "good ideas" and their learnings with the other teams (Wagner, 2008). The prototype was a scalable 60-90-120 bed secondary care, general acute services facility. This as to be a Greenfield site and the proposed solutions would be adaptable to varying site constraints. Adaptability was more focused on building design features and standardization of the key processes (clinical and logistic) than on a specific floor plan. Each of the teams would be compensated for their efforts by later being awarded responsibility for the delivery of a real healthcare facility (Tommelein and Ballard, 2011).

The Devenney Group took part in this effort, starting as early as 2006. The major design consultants that ended up being part of the IFOA team (Capital Engineering, TEE, TTG) were already on the team with Devenney at that time, but DPR Construction wasn't on any of the prototype teams. In 2007, Sutter Health assigned the SMCCV project to the Devenney Group and DPR Construction, since they were not satisfied with the General Contractor that the Devenney Group was initially paired up with. In early 2007, under the supervision of Sutter Health, the Devenney Group and DPR Construction self-assembled a team of design consultants and major trade contractors, which later became the IFOA team:

- Owner - Sutter Health
- Architect - Devenney Group
- General Contractor - DPR Construction
- Mechanical Systems Design - Capital Engineering
- Electrical Systems Design - The Engineering Enterprise
- Structural Design - TMAD-Taylor & Gaines
- HVAC Design-Assist and Construction - Superior Air Handling
- Plumbing Design-Assist & Construction - J.W. McClenahan
- Electrical Design-Assist & Construction - Morrow Meadows
- Fire Protection Design-Assist & Construction - Transbay Fire Protection
- Lean/BIM project integration - GHAFARI Associates

IFOA members were essentially selected on the basis of their qualifications, past experiences, familiarity with BIM technologies and interest in an IPD approach.

Sutter now owns the hospital, as the Eden district went away. The users were consulted and obviously had a say in the design process, but Sutter ultimately had the last word in the decision-making process.

It is also worth mentioning the Office of Statewide Health Planning and Development (OSHPD), which serves as the regulatory agency to enforce implementation of SB 1953. OSHPD is involved in the delivery of all acute-care facility retrofits and new construction in California, because they issue building permits. The Phased Plan Review process is detailed in section 4.1.4.

4.1.3 Contractual structure

The contract used on this job is the Integrated Form of Agreement (IFOA), a new form of contract authored by Will Lichtig of McDonough Holland & Allen. The IFOA has been used on several Sutter projects to-date, and is considered as one of the pioneering multi-party agreements. It was the first relational contract in the U.S. and the first multi-party form of agreement, to be later followed by ConsensusDOCS300 contract (supported by the Associated General Contractors of America), and the AIA's IPD forms of agreement. The IFOA emerged from an international symposium on relational contracting held by the Lean Construction Institute (LCI) in Atlanta in November 2004 (Ballard and Howell, 2005), at which Will Lichtig agreed to develop a form of relational contract to support Lean Project Delivery (Lichtig, 2005).

At the very beginning of the design process, the IFOA partners signed a preconstruction contract, the preliminary IFOA. During the course of the design, the project actors were basically paid according to a cost plus fee contract, but it was clear from day one that the IFOA contract would eventually be negotiated and signed closer to the start of construction, and that it would in effect cancel the preconstruction agreement. In August 2009, the 11 IFOA partners signed the final IFOA contract, which includes the Estimated Maximum Price (EMP), the IFOA equivalent of the conventional Guaranteed Maximum Price (GMP). The GMP approach uses the traditional method of shifting most cost risk to the construction manager/general contractor. With the EMP model, owner, designers, and major contractors share the risk of cost overruns and use financial incentives to align the interests of each member with the interests of the project (Darrington and Lichtig, 2010). As with a GMP, the owner pays the contractor for its actual construction costs plus a fee, but instead of the contractor "guaranteeing" that the project will cost no more than the GMP, the contractor and owner agree to share costs in excess of the EMP and the savings of a final cost below the EMP.

On this project, as on many IPD projects, a painsharing/gainsharing approach was chosen. The general idea for this approach is that the project team sets an amount for the expected design and construction cost and then shares any cost under-runs or overruns (Thomsen et al., 2009). On this job, all of the IFOA members' profit is at risk. The rules governing the Fee Pool amount determination are described below.

At the time the EMP was set, the IFOA team members agreed through negotiation on a profit markup used to calculate the expected profit. The "Expected Profit" is then determined by multiplying the profit markup times the estimated Cost of the Work of such team member as shown in the EMP (as adjusted for approved changes to the EMP) (Sutter Health, 2010). The Actual Cost of the Project determines the band in which the IPD Team falls, which in turn will determine the final value of the Fee Pool Amount (cf. Figure 3).

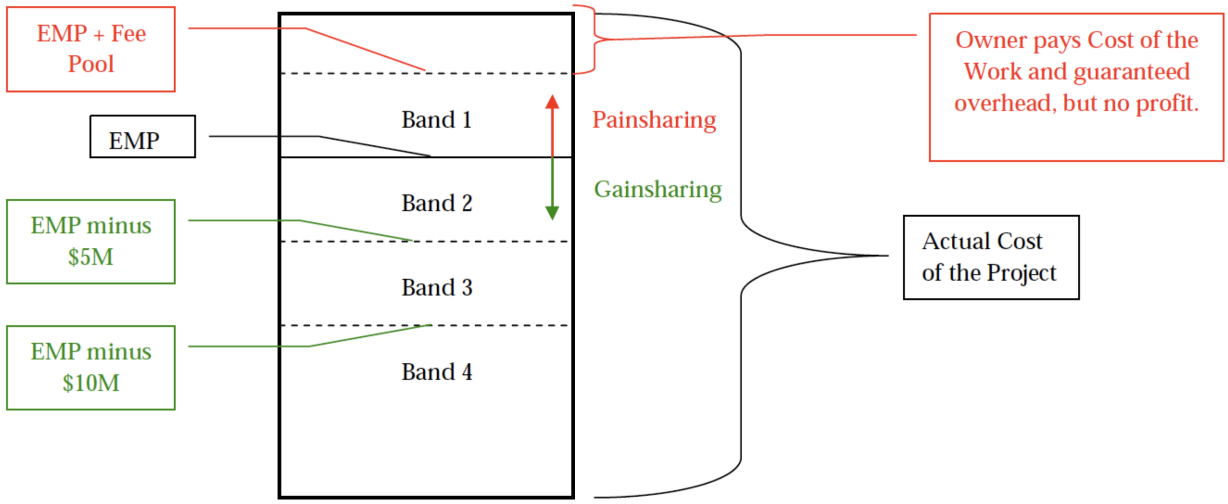

Figure 3: Description of the "Bands" which determine the size of the Fee Pool Amount

If the Actual Cost is at or above EMP (Band 1), the Fee Pool Amount will be constituted of:

- The total Expected Profit
- 50% of IPD Team Contingency unspent at time of Final Payment
- Minus the Amount by which the Actual Cost exceeds the EMP

It should be noted that the Fee Pool cannot be negative, meaning that the Owner bears the risk of large cost overruns by paying the Cost of Work and guaranteed overhead.

If the Actual Cost is less than EMP, the same amounts added under Band 1 will be included in the Fee Pool calculation, plus:

- Band 2: 50% of the Amount by which the Actual Cost is less than the EMP.
- Band 3: $2.5 million (from Band 2) plus 75% of amount by which the EMP exceeds the sum of [Actual Cost + $5M]
- Band 4: $6.25 million (from Bands 2 & 3)

The savings are thus shared between Sutter and the rest of the IFOA Team, incentivizing everyone to contain cost during construction.

4.1.4 Project timeline

As already mentioned, the Devenney Group and the design consultants took part in the co-opetition process from year 2006. During the first semester of 2007, Sutter Health, the Devenney Group and DPR Construction assembled the IFOA team, which got involved for the Validation Study in the summer of 2007.

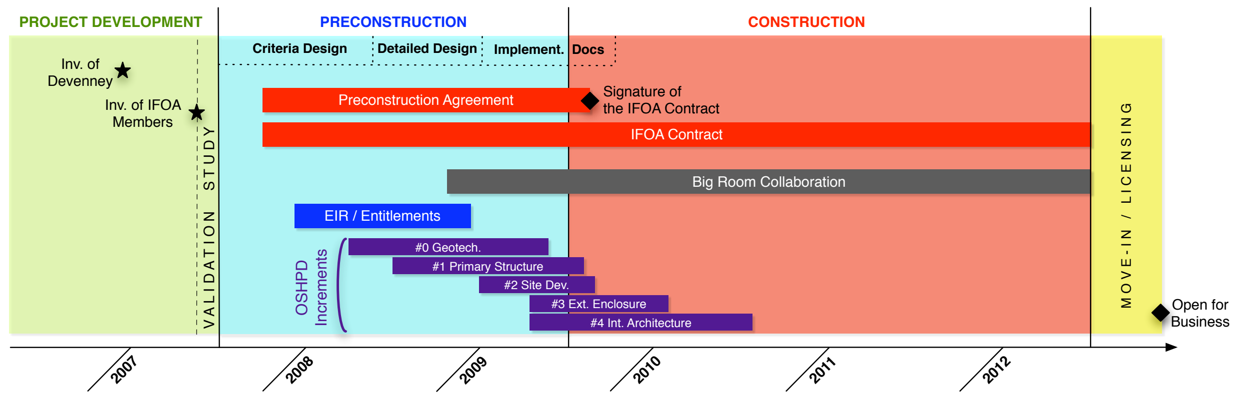

Figure 4: Project Timeline on SMCCV

As represented on Figure 4, the Preconstruction Agreement and the IFOA contract were signed respectively at the beginning of Preconstruction and Construction. Rather than the traditional SD-DD-CD framework, this project adopted the IPD phasing promoted by the American Institute of Architects (AIA 2007):

- Conceptualization
- Criteria Design
- Detailed Design
- Implementation Documents
- Agency coordination/final buyout
- Construction
- Closeout

These terms reflect the upfront collaborative efforts that take place at the onset of a project, notably in a BIM environment.

As already mentioned, the building permit is subject to OSHPD approval, the state regulatory agency for hospitals. Traditionally, OSHPD permitting can take 1 to 2 years in-between the completion of design and the start of construction of a new facility (Tommelein and Ballard, 2011). The increase in OSHPD-review lead times since the early 2000s led to a 2006 industry-academia initiative, called the "California Healthcare Facilities Project", driven by Professors Glenn Ballard and Iris Tommelein, Directors of the Project Production Systems Laboratory at UC Berkeley. By mobilizing all involved, and in a joint effort with legislative authorities, the industry was able to change legislation so that OSHPD could get involved in Phased Plan Review (PPR) rather than having to wait to start their review upon presumed completion of a design (the so-called 'Traditional' review process). The PPR process engages OSHPD early in the project design, continuing through the development and submission of documents during each the phases listed above (OSHPD, 2008). PPR allows for incremental reviews by "Segments", which define a specific part of the building or building system that is being submitted for review.

The SMCCV was one of the first projects to adopt this approach, in part because of a need to significantly reduce the project duration. The final document set including the structural package was submitted in December 2008, and the initial permit was received in June 2009, allowing the foundation work to start in July, while the rest of the project is being reviewed by OSHPD. As a result, the phases listed above were not followed in a linear way for the project as a whole, since at a given point in time, some parts/systems of the building were more certain than others. The construction is scheduled to end by mid-2012, allowing six months for licensing and move in by the hard deadline of December 2012 (Khemlani, 2009).

4.2 Implementation of TVD

This section is aimed at capturing how TVD has been implemented on the SMCCV project. The analytical framework presented in section 3.3 is used to present the mechanisms put in place to support TVD as well as the limitations or opportunities for improvement.

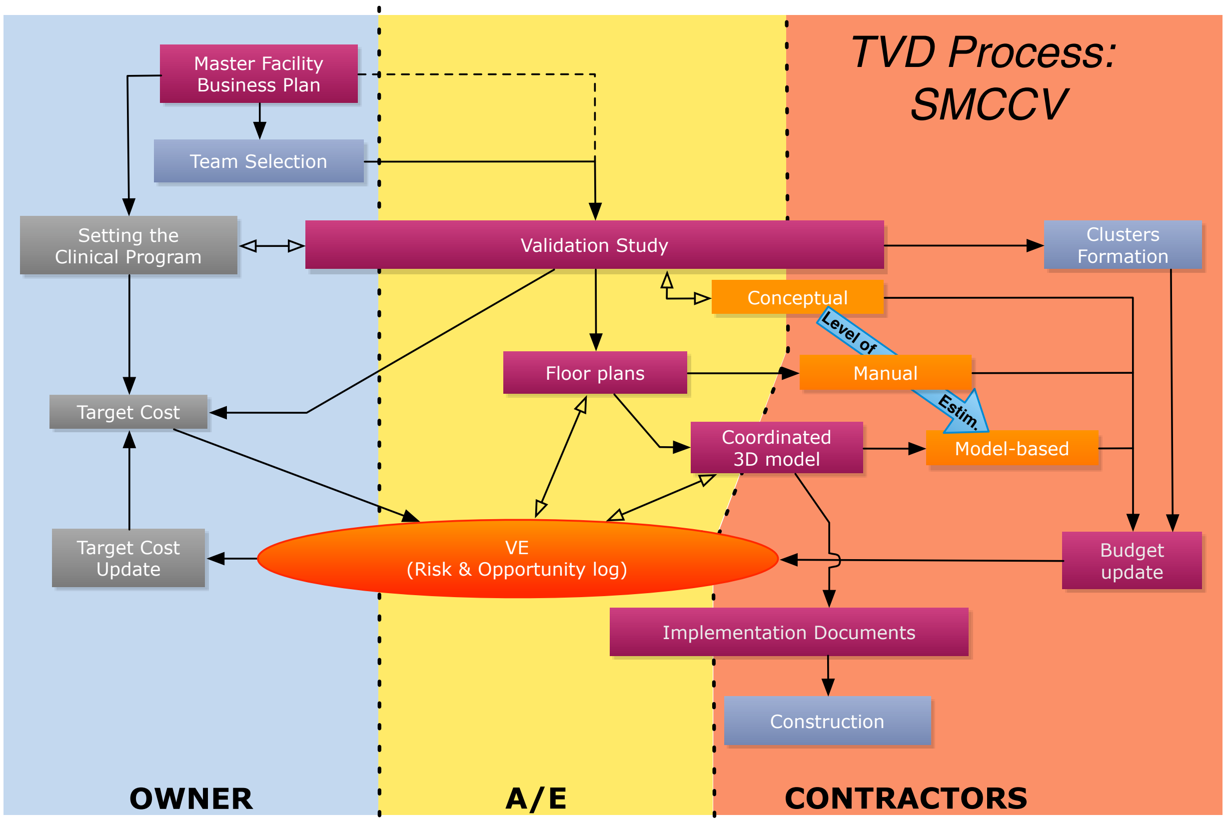

Figure 5: Target Value Design implementation on SMCCV

Figure 5 is a process map of the TVD process implementation, which portrays who of the Owner, Designers or Contractors is/are primarily responsible for each process and document relevant to TVD.

4.2.1 Organizing (preparing mechanisms for…)

4.2.1.1 Commercial terms & interests alignment

As already explained is section 3.1.3, a multi-party agreement (the IFOA) was adopted on this job. Sutter Health was really the driver in bringing this new type of contract and setting up the incentives plans. Early during validation, Sutter invited several times the team partners to its home office to familiarize them with the IFOA terms.

The contractual environment keeps the interests of IFOA members aligned for the whole duration of the project. During preconstruction, the team had to work together to get to an agreement and move forward to construction. The team needed to get the project cost down to an acceptable level so that everyone could feel comfortable enough to commit to the EMP. During construction, the IFOA members have all their profit at risk, but have their costs covered, following the painshare/gainshare approach described in section 3.1.3 and illustrated in Figure 6. If the team makes it to the "gainshare" area, a portion of the savings would be shared between the IFOA members, while Sutter keeps the rest. According to the designers, having their full profit at risk is relatively new to the profession, which made them a little nervous at the beginning of the project. However, the fact that their costs are fully covered is also a good guarantee for them, and they started feeling more comfortable with it as the project got on the right track.

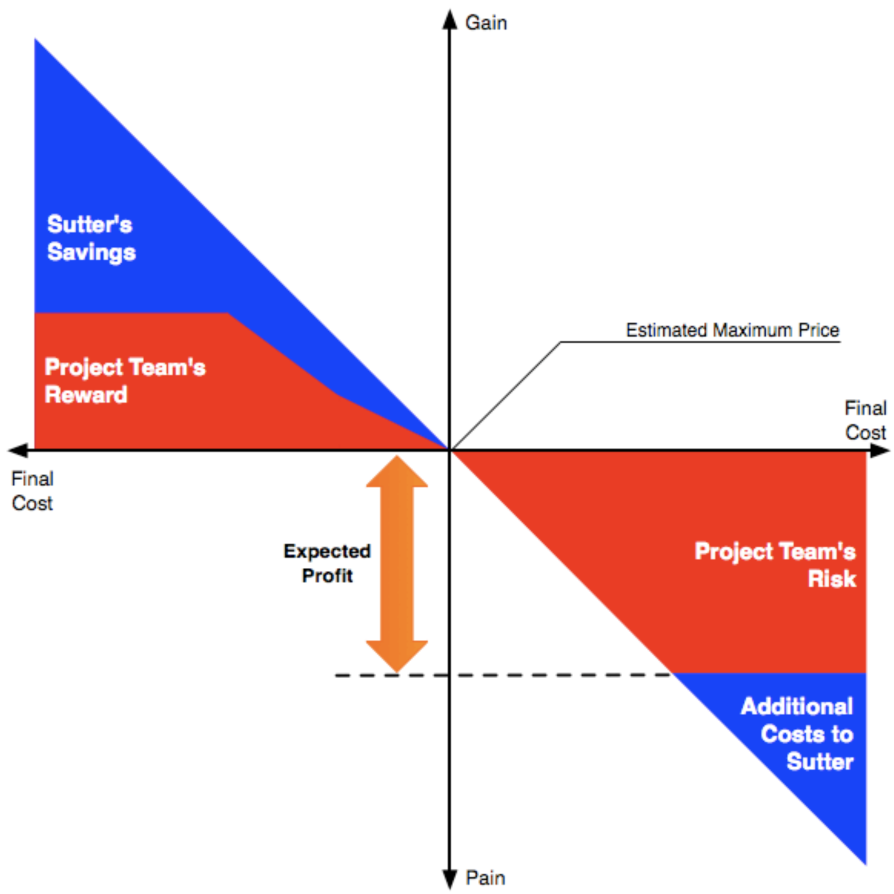

Figure 6: Risk and Reward approach on SMCCV

By sharing cost overruns or savings, the team's commercial interests are better aligned so that the major players have commercial reasons to mutually support each other in optimizing the project and collectively managing risk. This contractual environment is particularly suited for aligning interests of the IFOA members in the context of Target Value Design. However, only the major design consultants and trade contractors signed the IFOA, a decision that was subject to Sutter's approval. The Devenney Group and DPR Construction manage many consultants and subcontractors that are not part of the IFOA team.

Those partners, who are mostly contracted to DPR Construction with Lump Sum contracts, don't have as much interest in the project objectives and may behave more traditionally. Besides not having the contractual incentives, those actors tend to struggle both ideologically and financially with this collaborative approach. As illustrated further, TVD requires a mentality shift and a financial investment that may be difficult to accomplish for the sake of a single project with a limited scope of work.

Although working as a catalyst for integrating the team members and aligning their interests, the IFOA contract shall not be seen as a requirement for Target Value Design:

> *"I would just question the validity of saying how much the contractual relationship has to do with the efficacy and effectiveness of TVD techniques." (Designer)*

The project actors are all professionals and are not solely motivated by the financial aspects. However, aligning the commercial interests of the various companies allows them to release their employees to follow their intrinsic motivation to collaborate productively with others. As long as the individual has to protect his employers' financial interest in a zero-sum game, that intrinsic motivation is suppressed. In that regard, it will be interesting to study the application of the TVD process to non-IPD projects, such as the UCSF project (cf. section 6).

4.2.1.2 Integrated teams

The formation of integrated teams is obviously one of the key characteristics of an IPD project, and is a crucial prerequisite for TVD. On SMCCV, the General Contractor and the key trade contractors were involved in the project with the owner and designers from the early stages of design, during Validation, which allowed the major players to develop a much higher level of common understanding of the project. The contractors provided continuous input about cost, constructability, schedule and value, allowing the designers to make better decisions with fewer and less intensive negative loop-backs (Thomsen et al., 2009).

We should highlight the active participation of Sutter Health to make this whole process work, as put in evidence by the survey[6]. Many interviewees also underlined the interaction with Sutter Health: *"And it's been refreshing on this job to have interface with the owner, because usually, we don't have a tremendous amount of interface with the owner (a contractor)".*

Integration was fostered by physically co-locating members of the IFOA team, allowing for ease of physical proximity to address questions and solve problems. The IFOA trade partners devoted people full-time to this project, as opposed to the traditional process where they typically have people working on 3 to 4 projects at a time. This "Big Room" setting started in December 2008, and definitely contributed to create a collaborative environment in which everyone was easily accessible. The team was not fully, but partially co-located. Some of the designers and contractors are not local and came to the project site every other week or when requested. The rest of the time, they worked from their home office and were in contact with the rest of the team thanks to Go To Meetings.

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[6] Criterion 4 – the customer is an active and permanent member of the project delivery team – received a score of 4.8/5 (cf. table).

Every 2 weeks, everyone in the trailer took part in what is referred to as a "Big Room meeting". Those meetings played an important role in team integration, as everyone was aware of what was happening on the project and could give a contribution. However, by absolutely endeavoring to involve everyone, those meetings were sometimes not very prolific, as they were affecting only few people in the room:

> "*During one of the ones I went to, they did a presentation on lift equipment for heavy patients. They spent like 2 hours on the presentation. And except for where the supports were located in the ceiling, it really had no effect whatsoever on my trade. And that's just a small example. But I know this was a learning experience for everybody and I believe that DPR felt that if everybody was in the room, that everybody could contribute." (A contractor).*

Those meetings have an important cost as they represent a big time investment and lead to travel costs for the managers that were not working full time on the project. It appears that they could sometimes have been replaced by smaller group meetings, either onsite or via conference call. The right balance is difficult to find, as you would like to involve only the trades directly related to the subjects being discussed, without missing any input from anyone.

The optimal size of the integrated team is also an interesting question. On SMCCV, 11 companies are part of the IFOA team, which was perceived by the interviewees as a proper amount. Only the major design consultants and trade contractors that bring value during the design process shall be part of the team. For some scopes of work, the team actually gets more value by selecting a firm through hard price bidding, rather than involving it early in the design. There is a risk of waste in having too many people involved, as it may slow down the discussions. On this particular point, the architect reported: *"there really was a lot of waste having the whole team participate and going to the legal office in San Francisco and talking about entitlement".* Transbay, the fire protection contractor, wasn't involved during validation, but eventually signed the Preconstruction Agreement and became an IFOA member. According to some interviewees, Herrick Steel, the steel contractor, and Royal Glass, the glazing contractor, are companies that could have brought value by being part of the IFOA.

4.2.1.3 Integrated governance

An integrated team also benefits from integrated governance, a role assumed by the Core Group. As stated in the contract, *"[t]he "Core Group" is responsible for coordination and overall management and administration of the Project consistent with Lean Project Delivery principles. The Core Group includes an Owner's representative, an Affiliate's representative, an Architect's representative, a GC's representative, one selected member of the IFOA Design Consultants and one selected member of the IFOA Trade Contractors"* (Sutter Health, 2007). Like Big Room meetings, Core Group meetings are happening every 2 weeks. During these meetings, the Core Group reviews the progress of the project, discuss the budget evolution, the Risk & Opportunity log and pending Change Orders. The Core Group shall endeavor to make decisions by consensus, but in the event of impasse, Sutter has the last word in the decision-making process.

4.2.1.4 Joint responsibility, transparency

On most projects, the Architect and General Contractor are the 2 major players, and everyone else works for them and has to go through them. This is not the case on this project. On the first page of the IFOA contract, all the bubbles (representing the different contract signatories) touch each other's. And the project wouldn't have been so successful if there hadn't been such a group of people that truly put their humility in place to work in an environment that is truly represented by this first page, with no hierarchy:

> *"If you don't have a group of people that are not open enough to truly examine themselves personally, their company's processes personally, and be able to fight for doing what's right for that project and change the way they do things, you can codify all you want and all you're gonna get is mediocre results." (A designer)*

It all comes down to the people on the job and their openness to change. TVD is a really intimate process, as designers or contractors are traditionally not used to revealed their costs and markup. Over the course of the project, the schedule and budget became very transparent, which allowed anyone in the team to look at a number and question it: is it right, can we reduce it or bring more value? Everybody looked at everybody else's budget and challenged people's scope versus budget. This process was multi-disciplinary, and not confined to traditional silos.

Sutter Health really strived to establish this open book environment. Co-location definitely helped to make information more accessible and develop trust and team spirit. The IFOA members felt committed and really wanted to make this project work. But according to the owner, it took some time to get the team fully engaged in providing transparent estimates and having a joint responsibility approach. There was a cultural barrier that needed to be overcome before getting the whole team feeling accountable.

4.2.1.5 Functional interface

For each OSHPD increment, the basic workflow would be:

- Progressive refinement of the design model by the corresponding designers, with input from the corresponding trade contractors;
- Drawing in the 3D model, for most of the contractors' scope of work;
- Clash detection and coordination;
- Extraction of 2D plans, review and submittal to OSHPD.

The "Responsibility Matrix" clearly defined the degree of responsibility of each IFOA partner for any scope of work. According to all the interviewees, thanks to the Big Room setting, the degree of collaboration was substantial on this job.

Having an integrated team during design challenges traditional work processes. On a traditional project, a contractor is usually involved once the design is complete, and thus doesn't expect any changes from the designers. In an IPD setting, the contractors are modeling and pricing the job while the architect and engineers are continuing designing and dimensioning. Naturally, design iterations occurred, which created some rework and frustration on the contracting side.

Hence, the team members had many discussions to try to structure the work and develop a common understanding. The designers really had to understand what was important to the contractors and what changes made big differences in construction. On the other side, the contractors really had to understand why the architects needed to do things the way they did and how codes and OSHPD affected them. In a way, the engineers became the mediators between the contracting side and the architectural side. They had to work to find the common ground and to be able to achieve the goals for both. This implies changing the way work is usually done and find ways to be able to give reliable information to the contractors, still allowing the architectural side to have the freedom where they needed the freedom. As an example, the contractors have trouble understanding what deadlines for OSHPD mean. There were a lot of discussions around what the words "final" and "done" meant.

In the long run, those discussions are part of what made this project successful. It definitely constitutes one of the key lessons on this job. And it would be useful for future projects to characterize and codify this work structuring process. It should be noted that no TVD training was offered to the IFOA team.

4.2.2 Defining (ends & constraints)

4.2.2.1 Business Case

It is important to understand that this project was not driven by a business case, but rather by other requirements such as the SB 1953 seismic regulations. Sutter basically needed to replace the facility. Sutter's strategic business development group elaborated a Master Facility Business Plan that detailed the clinical program, which was, with a few exceptions, a replica of the existing facility's program. Based on data from the census of occupancy of the existing Eden hospital, they studied what they could afford at the site, and decided to spend a certain amount of money on this job, for a 130-bed facility. But how this number was reached was never shared with the team. The survey that was conducted for this research illustrates this lack of access to the business drivers[7].

It is hard to compare the approach followed on this project to the TVD benchmark for Business Planning, since the information isn't shared. In a way, an allowable cost was determined based on funding availability and the worth of the facility. Whether the worth was derived from a whole life study of the benefits in use is unclear though. And there is no transparency about how this allowable cost was set.

The allowable cost is what an owner is willing and able to pay to get expected benefits from use of a constructed asset. As such, this is the maximum that can be paid without violating return on investment requirements. This links TVD with target costing methodology in that the investor is managing 'product' profitability. In the case of construction, projects are those products. Basing project budgets on the owner's allowable cost protects the owner against poor investments and protects suppliers of goods and services from exploitation by owners.

The allowable cost may be close to, substantially above, or substantially below the market benchmark. If close or above, the project is feasible at face value and the owner may choose to set a target cost lower than the allowable. Suppliers can judge for themselves the appropriateness of the target and the probability of achieving it. If the allowable cost is substantially below the market benchmark, feasibility is not apparent and must be evaluated by the collective team, but the gap to be overcome is visible to all.

4.2.2.2 Stakeholder values

As already mentioned, 3 teams of designers and contractors worked on the design of a template hospital through co-opetition. In addition to help for team assembly, Sutter's ultimate goal was to merge the 3 designs into the ultimate hospital and pick the best of the best in all 3 of those. Because of the site

[7] The TVD benchmark components 2 and 7 received the lowest scores (respectively 3.2 and 3.5 on a 5-point scale) for this project (cf. table 3).

constraints, the team took some, but not all, of the efficiencies that came out of those studies to put into the Castro Valley program. Sutter drove those decisions, as well as which programs needed to be next to others, and so forth.

The clinical program, derived mostly from the existing Eden hospital, was pretty much locked during validation. According to most of the interviewees, it has been a very stable program since then. The schedule was pretty aggressive and the budget settled. In order to meet the timeframe and the budget, the owner could not make changes after validation. And it’s been managed very well in that regard. From the start, Sutter had been very clear about what they “valued” for this project: *“getting this clinical program for this much money overall on this date” (Digby Christian, Sutter Health).* In terms of design options and systems for the MEP of structural, Sutter didn’t have any specific ways for the designers to go about. They basically left it up to the designers’ expertise.

The only major change early during design was the displacement of the Emergency Department (ED) to another building. Everyone was trying hard to pack the clinical program into the building, but eventually realized that it wasn’t possible. As a result, the square footage increased from 214,000 to 231,000, and the target cost for the whole project was re-evaluated to $320,000,000 (instead of $300,000,000). But it was the only major change, and the budget hasn’t changed since then.

After validation, the users of the facility were consulted as well. Devenney was primarily dealing with the clinical users, while the engineers were in contact with the operators of the facility. Sutter dealt directly with the other stakeholders (OSHPD, County, City, etc.), with help from Devenney.

4.2.2.3 Plan validation

In June 2007, Sutter came to the designers and DPR to validate their program, number of beds, budget and schedule. They assembled the team, had a kick-off meeting, and started the validation study. Several concepts were considered, Devenney created a massing study and they ended up picking up one of the concepts. DPR was responsible for estimating the overall project, with input from the Design Assist (DA) subcontractors.

At that time, the structural engineer had to validate the main structure for the different concepts considered. MEP designers gave input on room sizes, looked at systems types and started to roughly size things. DA subcontractors were consulted for cost inputs on those systems. They had to confirm DPR’s estimates and make sure they understood the demands, needs and expectations of the client. The validation report, which was produced in 6 weeks, contains massing studies, a basis of design, basis of estimate, a budget and a milestone schedule. According to an interviewee, the team could have agreed on a better clear-cut definition of what was in the overall budget and of the breakout between owner’s and contractor’s scopes.

Sutter has a short-term contract for doing the validation study, precursor to the pre-con contract. In September 2007, Sutter funded the job. But the IFOA contract had not really been presented to the team by then, and so a lot of time was spent after validation to familiarize the team members with the contractual terms and to put Sutter’s plan in place, before actually starting the design. As already mentioned, the clinical program has been very stable. After validation, Navigant Consulting was asked to develop narratives for clinical space, but the respective clinical square footages remained almost identical throughout the whole project.

4.2.2.4 Target setting

During validation, the team agreed on an overall budget of $300,000,000. Before March 2008, the team was busy figuring out the contractual terms, going through the entitlement process and looking at mistakes in the validation study. *"So it wasn't moving into really more defined criteria design and detailed design at that time" (a designer).* Around March 2008, Sutter set the target cost for the whole project at $320,000,000. And it has never really changed throughout the whole design. Again, how they came up with this number was not shared with the team. Sutter made it clear that they wanted exactly the program that they asked for, on time and on budget, which is sadly already a big challenge in this industry. Saving money on the approved scope came second.

At the time, the current estimate (or Expected Cost) was around $360,000,000. So from that point, the team started working on getting the project down to the Target Cost by adjusting all the different discipline's scope and quality to be able to get there. It was about finding innovative ways to get from $360,000,000 to $320,000,000. So basically, over the course of design, the incentive was to get the expected cost down to the Target Cost, in order to reach an agreement and sign the EMP. Once the EMP was signed, the team is incentivized to contain costs in order to maximize its fee pool.

It is worth mentioning the central role of contingencies, which can conceal actual budget variations. Sutter is holding an Owner's contingency. The contractors are also asked in the contract to carry the "IPD Team Contingency" and an "Escalation Contingency" in their cost models. To quote the IFOA contract, "[t]he "IPD Team Contingency" is a contingency amount that is available exclusively to non-Owner IPD Team members who are a Party to this Agreement to address design errors and omissions and to pay for items that arise during the Construction Phase including, but not limited to scope gaps, acceleration for non-compensable delays and for unanticipated schedule changes."

The IPD contingency was set as a percentage of the overall cost pretty early on by DPR, considering how risky this project was. Early on, each contractor looked at their risk of inflation on materials and labor costs, which got captured in the "Escalation Contingency". As the design evolved, the contractors had more and more certainty about material costs. Once the EMP was signed, subcontractors were able to lock down their prices through early purchase of materials. From that point, any remaining escalation risk was carried by the subcontractors themselves. In the meantime, the "Escalation Contingency" bucket was used to cover things that ended up costing more than expected, while the "IPD Team Contingency" remained intact. In July 2010, the 2 contingencies were combined, to reflect the fact that they both carried risk and that a good amount of material costs had been locked in.

During construction, it was chosen to keep the "IPD Team Contingency" untouched as long as possible. So, according to the budget updates, the team was technically "over budget" until March 2011, but that was pretending that the $8,000,000 worth of contingency would be spent entirely. The idea behind this was to keep the people on the job motivated to try to find innovative ways to reduce the budget.

However, there are two issues in doing that. At first, the monthly billings are reduced accordingly, since they are calculated based on the difference between projected actual cost and projected EMP. Secondly, according to the contract terms, only 50% of the "IPD Team Contingency" will be added to the fee pool at the end of the job, while the fee pool would be reduced by the exact amount the IPD team is over budget. Therefore, contractors are incentivized to use the money from the "IPD Team Contingency" to pay for their rework, while Sutter might be tempted to argue about it in order to maximize savings. There could be some tensions at the end of the job around what constitutes an error or omission that should be taken out from the "IPD Team Contingency" or not.

For further information, contact Glenn Ballard, ballard@ce.berkeley.edu

4.2.3 Steering (means)

4.2.3.1 Cross-functional teams

The people on the job were organized in cross-functional teams (clusters) of designers and builders for major components and systems. The clusters gave some structure to the collaboration process, as the team was often invited to attend cluster meetings for budgeting or coordination purposes.

The clusters are particularly important for TVD, as the budgeting and value engineering efforts are organized by clusters. During Preconstruction, the budget was broken down according to the following clusters:

- PRE (Preconstruction)
- CA (Construction Administration)
- INT (Interiors)
- STR (Structural)
- MEP (Mechanical, Electrical, Plumbing and Fire Protection)
- ENV (Envelope)
- CIV (Civil)
- COM (Communications)
- FFE (Furniture, Furnishings & Equipment)
- OWN (Owner)

It is worth noting that the team was initially using a multi-disciplinary cluster for MEPFP, but realized later on that this was too big and ineffective. *"It wasn't efficient to talk about electrical matters with mechanical engineers in the room" (a designer)*. Also, they were wasting some time combining numbers together into an MEPFP cluster estimate. Therefore, after a couple of months, they decided that for budget purposes, it made sense to break them apart to provide more transparent and better quality information. And so, a cluster at this point is really a discipline.

As the overall expected cost was over the overall target cost, cluster targets were allocated to each cluster. The idea was to track the evolution of the clusters' estimate towards their target to make the teams accountable and to identify where the cost reductions were coming from. Even if there were discussions early on as to what innovations and potential savings the team members envisioned for their discipline, the same target cost reduction percentage was assigned to each cluster (around 4.5% in March 2009). Therefore, these targets didn't necessarily made sense, as the disciplines have their own specificities and may not allow the same flexibility at a same point in time. The way to see it is more an ultimate goal to promote innovation among the different disciplines. There were some scope movements across clusters, which made it hard to truly follow the progression of each cluster's estimate towards target. And if a cluster had happened to reach its target, they would probably have had a new target allocated to them if the overall expected cost was still over the overall target cost. There was no specific reward for a cluster that successfully reaches its target, as it could have encouraged undesirable behaviors. On that particular point, it should be kept in mind that one of the key goals of TVD is to optimize the whole rather than the individual pieces. Therefore, money should be able to move across disciplines.

Clusters were used to monitor estimated costs against target costs. There were constant discussions, generally led by DPR, about cost implications of design decisions. In the IFOA contract, it specifically says:

> *"IPD Team members shall bring forward within the design clusters, alternative systems, means, methods, configurations, site locations, finishes, equipment and the like that satisfy the general design criteria of the Project, but which result in savings of time or money in designing, constructing or operating and maintaining*

> *the Project, or increasing quality, constructability, or other measures of value and are cost neutral." (Sutter Health, 2007)*

In that regard, the clusters were the spheres where TVD was materializing itself, where contractors and designers were conducting value engineering in order to design the hospital to the targets.

In addition, cluster leaders were meeting regularly and frequently, with responsibility for evaluating TVD tradeoffs and opportunities (including function/cost trade-offs) and authority to direct value engineering and adjustments of the component/system costs up or down to maintain total project target cost.

4.2.3.2 Design planning

As already mentioned and represented by the timeline (cf. figure 4), the design was submitted to OSHPD through Phased Plan Review (PPR). Devenney had to give OSHPD their proposed schedule, increments and sub-increments. The whole team was consulted and involved in that process. After validation they actually signed a Memorandum of Understanding with OSHPD and agreed on the following increments by components:

0. Geotechnical Report
1. Primary Structural
2. Site Development
3. Exterior Enclosure
4. Interior Architecture
5. Seismic Anchorage

The integrated approach definitely influenced scheduling. It enabled to reduce schedule for OSHPD submissions by limiting OSHPD back-check submittals, as contractors could give constructability input early on. But as already mentioned in section 4.2.1.5, the way to structure the work around those increments had to be thought over, and there were a lot of discussions to make the contractors fully understand what the deadlines for OSHPD meant.

From those OSHPD submittal dates, a master schedule was developed in Primavera. To plan the work during Preconstruction, the team used a program called SPS. It is a task management system that creates users' tasks, links between tasks and durations to drive commitments. This system enables LCI's Last Planner System® through the following features[8]:

- Uploading tasks from master, phase & lookahead schedules
- Facilitating constraint analysis of activities
- Automating the creation and updating status of production plans
- Generating PPC & Reasons for Non-Completion reports.

Ghafari Associates, process consultant, was managing the SPS system, facilitating the planning and sequencing of activities, and keeping track of the reasons for non-completion. Instead of pull scheduling, Samir (Ghafari) prefers to talk about "process mapping design". The team members were invited to sequence tasks and activities on the wall with the help of sticky notes. This whole process played a major role in work structuring.

[8] Retrieved from the SPS website on 06/02/2011: http://www.strategicprojectsolutions.net/

PPC was tracked during preconstruction. Since interior construction started, the team used Vico software for planning the work and could not figure out how to incorporate the PPC metric. At the client's request, Last Planner, use of the SPS software, and PPC tracking were re-initiated later in construction.

4.2.3.3 Cost modeling

One of the core concepts of TVD is that the team should design to targets and to the owner's values. Among other things, it requires rapid costing of the design, to proactively influence it through value engineering. Ideally, the estimating process would be completely automated to provide near real-time cost input. On this project, Sutter was asking for cost estimates that should be:

- Frequent (to follow the pace of the design as closely as possible);
- Reliable (to be in line with the design);
- Transparent (to allow anyone to look at each other's numbers to find cost saving measures).

Sutter and Ghafari imposed a 2-week cycle for budget updates, which was a challenge impossible to meet with traditional estimating methods. Sutter encouraged each company to come up with their own way of doing it faster and more reliably, and for some scope of work, the contractors relied heavily on model-based estimating to meet the owner's expectations. Model-based estimating is the process of integrating the object attributes from the 3D model of the designer with the cost information from database of the estimator (Tiwari et al., 2009).

It should be kept in mind that the estimates obviously did not come from the model right at the beginning of the design. It was an evolution over time from conceptual to manual to model-based estimating, as put in evidence by the budget reports that kept track of this distribution. Also, at a certain point in time, some parts of the design were more certain than others and were estimated in different ways. The team started getting stability on the estimates piece by piece (both in terms of spatial distribution and major specialty systems) and progressively came closer to more realistic numbers. Hence, at a given point in time, the team would do electronic takeoffs for certain things and do more conceptual estimates for other items. The frequency of the estimate updates evolves throughout the project. It used to be a 2-week cycle, which was in line with the big room meetings. When the design was basically complete (approximately end of DD, January 2010), the team decided to adopt a monthly cycle.

Table 5: Software used on SMCCV and ABSMC

Trade	3D modeling tool	Model based cost estimating tool	Traditional cost estimating tool	Clash detection tool
Architectural	Revit	Innovaya/Timberline	-	Navisworks
Structural	Revit/Tekla	Innovaya/Timberline	-	Navisworks
Exteriors	Tekla	-	-	-
Interiors	-	-	On-Screen Takeoff	-
Mechanical	CAD-Duct	-	Quickpen	Navisworks
Electrical	AutoCAD MEP	-	Excel	Navisworks
Plumbing	CAD-Pipe	-	Quickpen	Navisworks

DPR used its own estimating software (Timberline), which contains a lot of historical data, to assemble the budget. For each of the different components of the building, the estimates progressively got more detailed, as designers were providing more information to the contractors. For instance, instead of having only 1 line item in Timberline for flooring, DPR started breaking it down once they had more visibility about the layout of the floors and the types of materials desired. DPR ultimately automated the estimating process for some of its self-performed work (drywalls, framing, concrete, doors…), as quantities were ultimately pulled out from the model and dumped into Timberline automatically.

The tools used by the different trades for 3D modeling and cost estimating are summarized in Table 5.

The article "Model Based Estimating to Inform Target Value Design" (Tiwari et al., 2009) gives more details about the implementation of the model-based estimating process and the tools used on this project. Figure 7 is a flow chart representation of the estimating process. It depicts how the cost estimates are assembled, by showing the different flows of information.

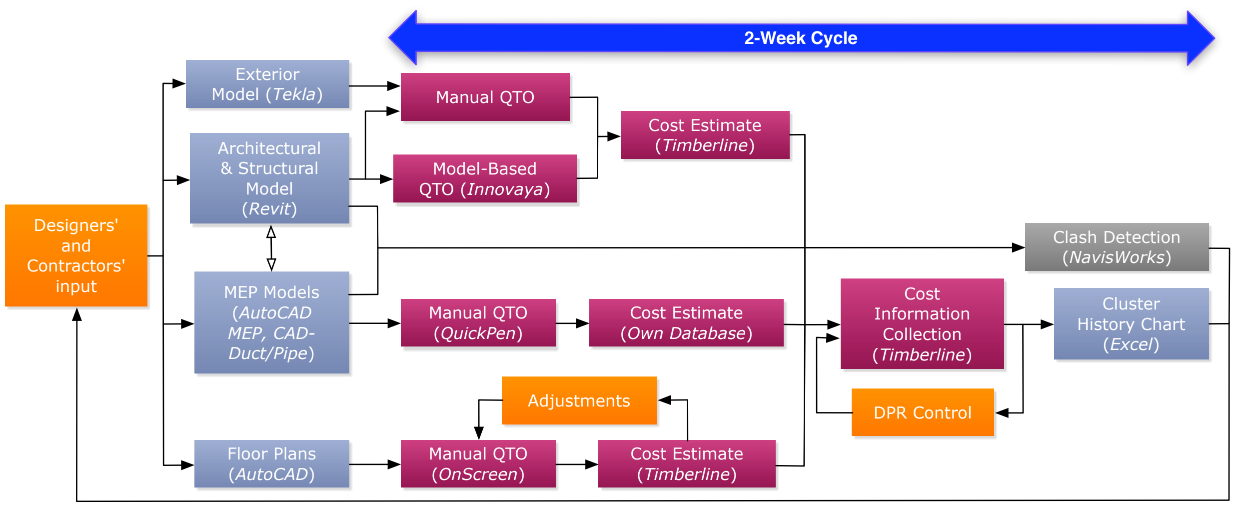

Figure 7: Estimating process on SMCCV and ABSMC

The **exteriors** (skin, curtain walls, etc.) are modeled in Tekla, and are manually estimated because the skin system is very complex and limited in scope.

The **architectural** and **structural** elements (steel, structural concrete, doors' frames and hardware, drywall and associated frames, casework, medical equipment support, etc.) are modeled in Revit. For those elements, there has been a transition over time from manual to model-based estimates. For model-based estimating, DPR is using Innovaya as the middleman software between the model in Revit and the estimate in Timberline.

The **MEPFP** elements are modeled in AutoCAD-based software: CAD-Mech, AutoCAD MEP, CAD-Duct and Sprink CAD. Those models could be exported into Revit (as an IFC or dwg file format) for visualization purposes. The MEPFP subcontractors are using their own estimating software, which are not integrated with their 3D model. Even though they are getting some quantities input from the model, they kept doing traditional manual QTO (QuickPen) and using their own historical cost database.

The **interiors** were not modeled on this job. When DPR started having interior documents (beginning of 2009), the team did comprehensive takeoffs approximately every 4 months, depending on the timeframe in which the architect would produce new/updated floor plans or finish schedules. The designers were basically manually translating what they had in the model into 2D documents. The first real set of floor drawings was the first submittal package to OSHPD (for the interiors), issued in February 2010. For the takeoffs, DPR is using "On-Screen Takeoff", a program that enables to upload a floor plan up to the screen and provides tools to do the takeoffs. This process is quite time consuming, which is why they do it only when there were significant changes in the design. For the 2-week budget updates cycle, the interior team would simply do minor adjustments.

All the cost information data was then assembled manually in Timberline, and used to update the budget charts every 2 weeks. DPR required every company to report their numbers in a specific format (labor, material, equipment, exterior work, administration, escalation...). The numbers were combined in an excel spreadsheet and manually plugged into Timberline. For each cluster, someone from DPR was responsible for getting an understanding of any change of scope and making sure nothing was missing or got duplicated.

How can the estimating process be improved? Can the team, thanks to model-based techniques, provide more transparent, faster and more reliable estimates? There is obviously room for improvement here, and the following areas have been identified:

1. <u>Sharpen the initial setup</u>

   Based on what happened on this job, the process of breaking down the overall budget in smaller pieces could be improved on future projects. There were initially a lot of grey areas that were determined progressively. For future projects, "it would be really valuable to set up clusters in advance and have everyone agreed on the expectations of what is included in what cluster" (Elke, DPR). Therefore, it's mostly about planning in advance the clusters' definition and then sticking to it throughout the project.

   Also, it would have been beneficial to know from the beginning how the different items will eventually be estimated and what steps should be followed along the way. Which program will be used? How is it going to be reported? The team should start planning the estimating process as early as possible (end of conceptualization) and try to stick to it. A lot of estimating techniques that have been implemented on this job were relatively new for the industry. Hopefully, this process will be more efficiently executed in future projects.

   The transitions from one estimating method to another can be facilitated. With experience, the different players will probably know better when is the right time to switch from conceptual to manual to model-based estimating. One of the challenges is the possible omission and duplication of items when changing the estimating method. The use of visual tools to compare the quantities that are taken off manually and the ones taken off from the model could probably help.

   A problem than can be easily overcome in the future is the lack of confidence in the numbers taken off from the model. Because model-based cost estimating was new, DPR needed to verify the accuracy of what was shown/tagged in the model by doing traditional takeoffs. Sutter reproaches DPR for double-checking quantities for a little too long. In future projects, DPR's internal division should feel more comfortable in doing model-based estimates, and we can reasonably expect that the quantities will need to be double-checked manually for a shorter period of time. However, it does require to be sure that the information is well inputted in the model, as a wall not properly tagged would not be included in the takeoff for instance. The architects, who are the ones modeling in Revit, should do their own quality control, and be sure to update the model as design progresses. Once again, it requires the interests of architects and contractors to be aligned, which the IFOA environment is aiming at achieving. DPR had been working early on with the architect to make them aware of what items DPR as a contractor would need to have modeled and the format of how they would need to model it. Improving model-based estimating thus requires a better coordination with the engineers/architects and more QC upstream.

2. <u>Model more</u>

For instance, the interior finishes were not modeled and could be modeled in the future to improve the estimating process. Not modeling the finishes is less important from a coordination standpoint, as they are generally not a source of conflicts. However, doing manual quantity takeoffs for the interior finishes was extremely time consuming. Pulling out quantities directly from the model could save a lot of time and money, especially if there are numerous revisions. Furthermore, maintaining an up-to-date model allows the budget to continuously evolve with the design, instead of an incremental progression dictated by the issue of new plans from the designers. This is beneficial from a TVD standpoint, since we want the cost estimates to be as much in line with the design as possible in order to better inform design decisions. In addition to being faster, model-based estimating also reduces scope for errors and omissions. But again, model-based estimating requires the architects to put more effort in modeling everything properly and then keeping their model up-to-date. Although challenging, we can reasonably think that the IFOA is the perfect contractual environment for allowing this effort transfer from the contractors to the designers.

However, it is true that one should not be blindsided by the wish to systematically use 3D modeling. What matters the most is that the numbers are consistent and can be updated quickly and reliably. Can we cost the price of doing real time estimating? How can we speed up the estimating process and at what cost? In the case of the interior finishes for instance, modeling everything would probably have been beneficial, as they had to do comprehensive manual takeoffs 5 different times. It might be hard to know in advance which method will be the most cost effective, as we don't know in advance the number of design iterations. Also, turning to model-based estimating may be more time consuming and costly initially (building the cost database, cultural shift, software training, etc.). But in the long run, model-based estimating should take less time, which necessitates a long-term vision not limited to the life of a single project. The issue here is whether design and construction companies see this project as oddball or as indicative of future project delivery.

3. <u>Use the model more effectively</u>

Out of everything that was modeled, only a portion of it was model-based estimated. When the EMP was signed by mid-2009, 86% of the cost estimate was coming from the model for DPR's self-perform work. But overall, only 35% of the cost estimate was model-based, while 20% and 45% of the cost estimate were respectively conceptual and manual based.

The model cannot capture everything properly. Some elements may simply be too complicated architecturally to be drawn in the 3D model. Some expertise is required to properly assess the quantities and costs associated with site installation. It is important to make here the distinction between quantity takeoffs and cost estimates. Although we can imagine that the model can ultimately give all the quantities automatically, costing everything seems more problematic. Labor and equipment is not systematically included in the model. Fixed labor and equipment rates could be applied on the quantities that come out of the model, but it would only give a rough estimate, which is not the point here. It wouldn't take into account the special conditions of the site. For instance, if this is a very congested area, it may need the subcontractor twice as much time to install that piece. That is something the model can't really tell, which is why the human factor is still needed. Also, model-based estimating cannot be used when the cost depends on the duration of several activities and is not based purely on the 3D element (temporary equipment, cranes…). Therefore, someone will always be needed to look at the special conditions and constraints, and make the final assessment based on his/her experience. This is why a completely automated process (you see a clash, start moving something in the model and directly see the dollar impact of the change) is a utopia.

The MEP subcontractors and some other trades are using the model for clash detection and the production of construction/installation documents, but they are still doing traditional QTO with their own software. MEP subcontractors were able to pull out some quantities from the model, but were never able to capture everything. The use of scrap factors is not inherent to an estimating method, and it could easily be automated with the help of an estimating tool. To what extent is the amount of information that can be put in the model limited? Specifying the gauge of a metal for instance is simply a problem of tagging. It seems like the MEP subcontractors have the capabilities of modeling everything. But it might not be worth paying a modeler to draw every single hanger, when those can easily be placed on the site by the installation crews without the help of the model. Having a completely automated cost estimating process might be difficult to achieve, as the model won't be able to capture everything (labor, equipment, special conditions…). But we can at least imagine pulling out quantities directly from the model and price them based on suppliers' input.

The fact that the MEP subcontractors use BIM for coordination, but do traditional QTO based on 2D drawings is not very efficient. In addition to the time required to do the manual estimates, there is a higher risk of errors, as the 2 models are not fully in line. In the future, can we imagine doing both coordination and cost estimating using the same model? The technology might not allow it, but we should try our best to develop integrated interfaces that enable the different trades to use the same platforms and avoid wasting resources drawing on different models for instance. On this project, there have been talks about using CAD-Est, the new program that TSI (Technical Sales International) came up with. It is the preferred model-based estimating tool for CAD-Duct and CAD-Pipe, and would directly tie the coordination process into an estimating program. But it wasn't implemented, since TSI was never able to demonstrate that it worked. The different subcontractors agree that it might be possible to do cost estimating directly from the model to some extent in a near future. It should be kept in mind that purchasing a 3D modeling tool and training detailers to use it represent a massive commitment that most companies cannot make for the purpose of a single job. It represents a long-term investment. Who will pay for the transition to model-based estimating: the owner or the interested trade contractors?

4. <u>Automate the information flow</u>

When doing cost assemblies, the estimators have to plug in the quantities manually into Timberline. In addition to wasting time, copying and pasting the information increases the risk of error. Could the information flow be more automated? The team members should try to utilize more integrated software platforms to have less interoperability issues. We can imagine creating plug-ins so that the information is dumped automatically into Timberline for example.

Budget charts were developed every 2 weeks, and discussed during Big Room meetings. Trending and visual reporting was something Ghafari worked on throughout the design. The budget reports were to be very succinct, and included a single sheet that would show where the team was financially on the job (cf. figure 8).

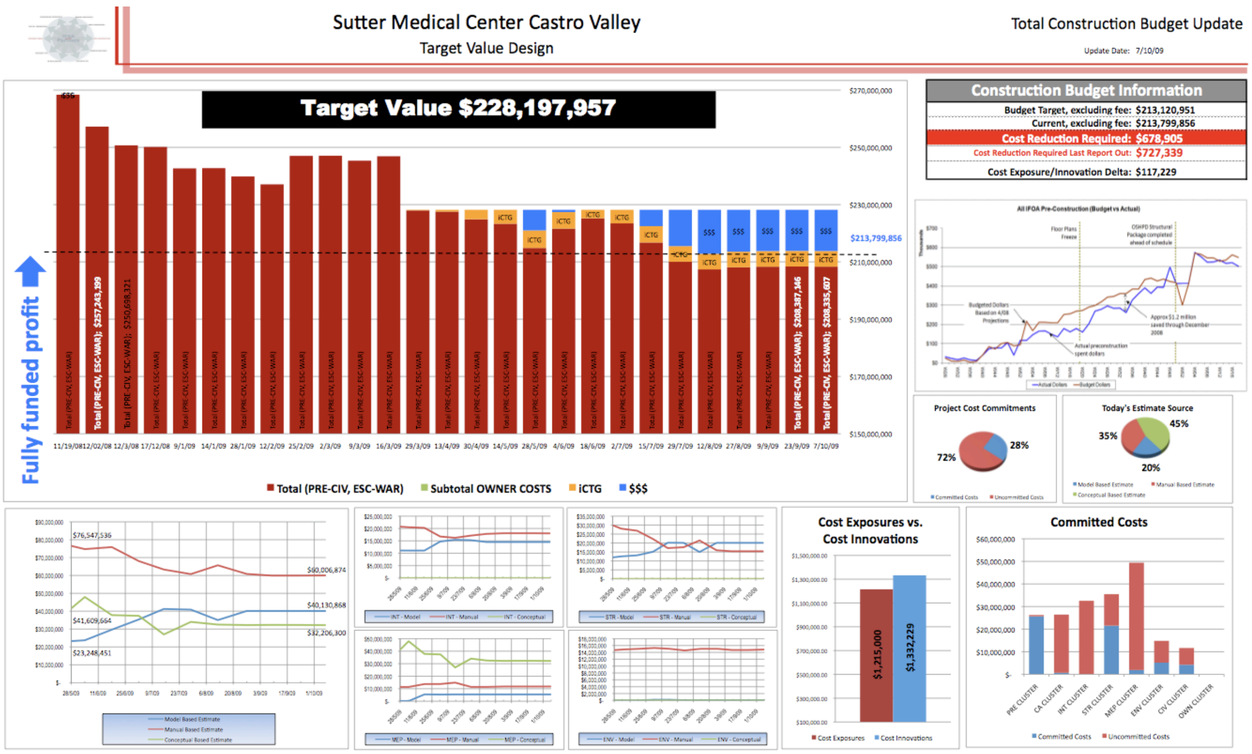

Figure 8: Budget Chart on SMCCV, taken from the 10/07/2009 Cluster History Report

This one page summary includes:

- Major budget indicators (EMP, actual cost, projected cost of risks, projected profit, required cost reduction…);
- A chart showing the evolution of the cost of work, internal contingency and shared profit;
- The potential risks;
- The committed costs by cluster;
- The estimate source (% model-$ based, % manual based and % conceptual based).

Budget reporting was helpful to inform the team quickly about where the project was going financially. Having each other's numbers accessible also helped finding synergies and collaboration ideas.

4.2.3.4 Analysis of alternatives

To a relatively large extent on this job, designers were developing design alternatives with cost, constructability and schedule input from the contractors. For the electrical trade, the first part was to look for specification modifications that would enable to use a less expensive product or a product easier to install. Once the designers started laying down the big pieces of equipment, the contractors were proposing alternative products that delivered greater value. This seems to have been the case for most of the trades, as designers were working hand in hand with contractors:

> *"And often our designs were done with 2 people holding the pen. So the cost input was usually immediate and continuous. So usually, we got the input before we even put something on a piece of paper. So it was a very real-time effort." (A designer)*

In a way, this intense collaboration reduces the cycles that may happen on some TVD projects where the designer produces a design, which gets priced, and then reworks on the design based on contractors' input. This approach was an additional thing that was going on during design, which took up some time, but without being cumbersome.

To structure a little more the value engineering process, Sutter developed the Risk & Opportunity log process. This log is an excel spreadsheet, part of the budget updates' set of documents, that was discussed during Core Group meetings. As represented on figure 9, it was used to bring up any risk item or value engineering opportunity that any member of the team would identify. A Risk is basically any item that was not anticipated and may lead to a cost increase, whereas an Opportunity would be an idea to deliver the same value for less money or a greater value for the same price. If relevant, an item would be added to the log and its cost impact (cost, schedule, quality, etc.) would be evaluated by the affected trade(s) over the next couple of weeks. During the next Core Group meeting, the team would assess the likelihood that the risk or opportunity will happen. The philosophy was to consider any risk or opportunity, even if it had little chance of happening. Depending on the likelihood, the team would then choose to abandon the change, keep it in the log or incorporate it in the next budget. If it stayed in the log, the next budget would incorporate it as a risk or opportunity, calculated by multiplying its magnitude by its probability. This log allowed to track items and was shared with everyone in the team.

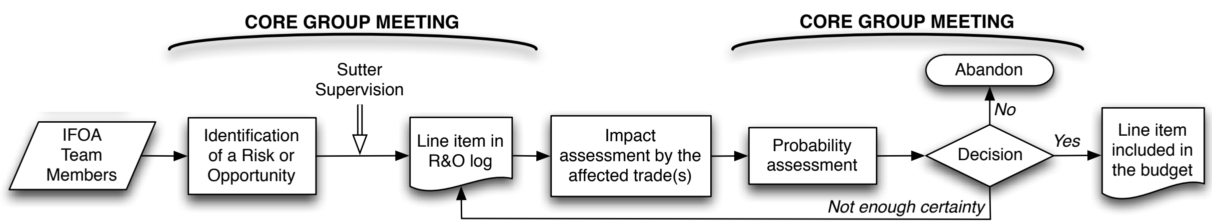

Figure 9: Risk & Opportunity log process on SMCCV

In a way, the Risk & Opportunity log was really the central piece of the TVD process, as symbolized on figure 5. Even though value engineering was also happening implicitly through discussions, this process was really the visible part of the TVD effort. It should be noted that owner-driven change orders would not be included in the Risk & Opportunity log. Consequently, the Target Cost or the EMP should not fluctuate after an item has been accepted. This log is really to structure how the IFOA team members get to steer their current estimate towards the Target Cost, and to keep track of that effort. The project team also used the A3 process to document owner-driven changes. However this approach wasn't as extensively followed as on ABSMC (at least not as early), which is why it will be further detailed in section 5.2.3.4.

4.3 Results

4.3.1 Budget evolution

The most relevant metric to appraise the success of TVD implementation is the evolution of the gap between Expected Cost and Target Cost. The analysis at this time will necessarily be incomplete as the project is still under construction. The TVD process really ends at the completion date of the project, once the facility has actually been built to targets.

Figure 10 shows the evolution of the budget from the end of the validation study to this date. It displays the progress of the overall project Expected Cost towards toward the overall project Target Cost, as well as the progress of the projected Actual Cost (including Target Profit, but excluding Owner's costs) toward the projected EMP, once the latter had been signed. The gap between projected Actual Cost + Target Profit and projected EMP represents the change in profit. As of today, the project is on budget, but the IPD contingency was left almost intact until March 2011, as explained in section 4.2.2.4.

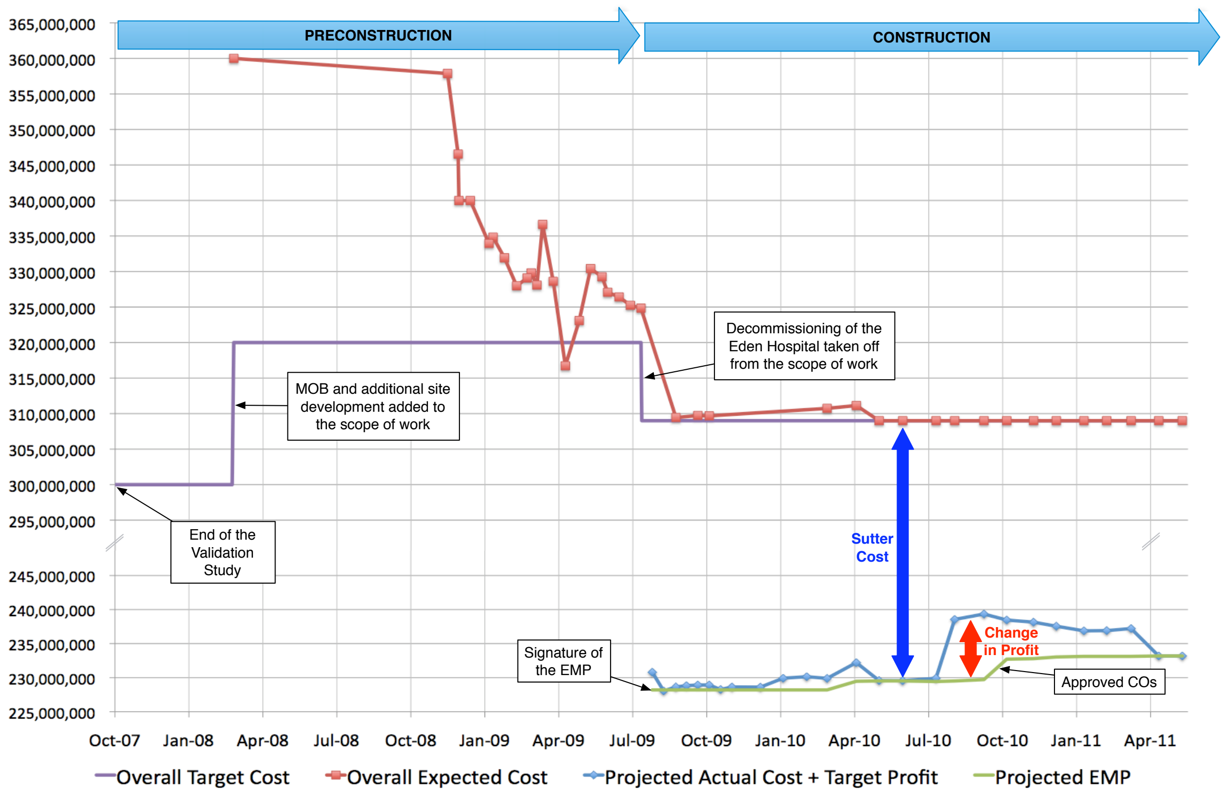

Figure 10: Budget Evolution on SMCCV

Establishing an actual cost reduction metric is challenging and should be done cautiously, as it is easy to manipulate the numbers to convey a particular message. Should we consider the overall cost or exclude owner costs? What initial estimate shall be considered? How shall we account for scope changes and change orders? Depending on the answers to those questions, the result might be quite different. At the beginning of preconstruction, the Expected Cost was $40,000,000 above the Target Cost, which represents an 11% cost reduction. Even though the project budget had been reset to $309,000,000 due to a scope removal, it is fair to say that the IFOA team managed to make up for that initial gap and reached an agreement when signing the EMP. It remains to be seen if the project will actually be built for that amount. But we can fairly say that the current estimate for the overall project cost is 11% below an early design estimate that can be characterized as the market cost. Again, one should not be blinded by this number, but should put it in the right context and appreciate the other benefits of TVD that will be further described.

4.3.2 Cost reduction drivers

It is legitimate to ask ourselves the question of the origin of the cost reductions. Was the initial estimate simply too conservative or did the team truly innovate to meet the client's targets? It seems to be a combination of several factors:

- **The economic situation.** The economy severely turned down in the past few years, and consequently people got "hungrier" and became more aggressive price-wise. It definitely contributed to cost savings as materials and subcontractors' services could be bought for cheaper than expected initially.
- **Less padding in the estimates.** It is not to say that the initial estimates had too much padding built into them. But the first guesses from the contractors were based on similar projects that did not necessarily promote the same level of transparency on costs. As the budget became very transparent on this project, there was less opportunity to pad the estimates, but more importantly less need to do so. Transparency reduces the stacking of CM/GC contingency on top of trade contingencies. The environment and the collaborative approach contributed to create a lot more certainty about the numbers. And as a logical outcome, contractors have less risk to manage and can provide more authentic numbers. If there was padding, it was really open, transparent and only when it made sense for the team.
- **More cost inputs from contractors.** Thanks to this integrated approach, designers were developing design alternatives with real-time cost input from the contractors. Contractors are obviously more knowledgeable about what would be cheaper to install, how the systems layout influences cost, which cheaper product could be used if the specifications were changed a little, etc.
- **Innovative ideas.** Numerous value engineering ideas were proposed by the team through the Risk & Opportunity log process and eventually contributed to reduce the budget. To give only one example, the architect decided to move the central plant out of the building. They decided to have a central plant away from the building, rather than within the building, where construction costs would be much higher since the requirements are different.
- **Synergies.** Having transparent estimates and an integrated team enabled to find synergies. As an example, each contractor generally hire their own guys to do their fire stopping if they have any penetration going through walls that needs fire protection. On this project, DPR decided to manage it and outsource the job to a single subcontractor, which saved the project around $50,000. Many other services like waste removal and clean up were also combined.
- **Higher productivity on site.** Designers drew the systems with a lot of constructability input from the constructors, which led to higher productivity rates during construction. The BIM coordination and clash-detection greatly contributed to increase productivity. Some contractors like Superior Air Handling are also using standardization tools like prefabrication to facilitate the installation on site and ultimately improve productivity.

4.3.3 An innovative project?

Were the systems chosen particularly innovative? Probably not too much, but what had been really innovative was the extent to which the team designed the hospitals to the customer's targets.

The structural systems are probably the most innovative component of the building. Because of the proximity to the Hayward fault, the seismic requirements were extremely constraining. TMAD Taylor &

Gaines, the structural engineer, managed to make it work, with a design combining concrete and steel, for a price comparable to other projects.

The hospital will get the LEED silver certification in the state, and this was not achieved without being innovative. But the innovation was almost natural, stemming from this collaborative approach. The team designed a relatively conservative hospital, using conservative construction techniques. But it's innovative enough to be able to meet lofty goals. To take an example, the HVAC system is not really "exotic" or using the most innovative products in the trade. But it is a robust system, not oversized and that has been optimized to meet the client's goals. So the biggest innovation comes from the fact that the systems were designed really right.

More generally, this process increases the length of the upfront and shortens the backside. The design is more accurate when construction starts, which limits "bad surprises" and allows more flexibility. Thanks to the level of integration and coordination, the MEP systems should be fully installed in June instead of September as originally planned. This illustrates the innovative nature of the design, which proved to be easily fabricated and constructible. Also, we can note that some of the tools used to support TVD were innovative. The extensive use of model-based estimating, relatively new to the industry, can definitely be qualified of innovative.

To conclude, rather than the product by itself, the process of designing this product has been extremely innovative.

5 Alta Bates Summit Medical Center Patient Care Pavilion

5.1 Project background

The Alta Bates Summit Medical Center (ABSMC) project presents a lot of similarities with the SMCCV project: same project size, same team members, same contract, a lot of similar processes, etc. Consequently, the processes that were implemented on both projects won't be described in as much detail. We will highlight here the differences and analyze how they affected the TVD application.

5.1.1 The product

The new Alta Bates Summit Medical Center Patient Care Pavilion will house 238 medical/surgical and acute rehabilitation beds[9]. The facility consists of two major components: a patient care tower and a basement and rooftop central utility plant. Like on SMCCV, the main purpose of the project is to perform a seismic upgrade of the acute care patient facilities in the Merritt Pavilion, so as to meet and exceed the seismic safety requirements of Senate Bill (SB) 1953 (Devenney Group, 2008). The building is eleven stories in height above grade and has two levels below grade, providing approximately 230,000 sq. ft. of new space. With 184 feet above ground, this building will be the tallest structure on campus, visible from many surrounding areas and symbolize the future of healthcare at Alta Bates Summit.

Figure 11: The new ABSMC Patient Care Pavilion[10]

Although providing approximately the same square footage for a similar budget (cf. table 1), this project presents some differences with SMCCV. This project is a patient tower, and therefore does not include surgery program in it, but offers 110 more beds. Whereas the building at Castro Valley is relatively

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[9] Retrieved from DPR's website: http://www.dpr.com/projects/healthcare/ (last accessed on 06/02/2011)

[10] Retrieved from Sutter's website: http://www.sutterhealth.org/about/new_hospital_construction.html (last accessed on 06/02/2011)

isolated from the current hospital, the new tower at Alta Bates is higher and right in the middle of existing facilities that must remain functional during construction. The job includes about 20 million dollars of make ready work improvements and demolition.

5.1.2 Project actors

Degenkolb Engineers, structural engineers, have been working on the campus since 1996 on their seismic compliance issues. When ABSMC started the master plan exercise, Degenkolb was working with the architect at the time, Jonathan Bailey. But when ABSMC actually decided to do the project, they paired Degenkolb with Devenney, and the team got assembled from that point. A lot of the actors on ABSMC are also on board on the SMCCV project. Here is the list of the 12 IFOA members[11]:

- Owner - **Alta Bates Summit Medical Center** / Sutter Health
- Architect - Devenney Group
- General Contractor - DPR Construction
- Mechanical Systems Design - **Ainsworth Associates**
- Electrical Systems Design - **ECOM Engineering**
- Structural Design - **Degenkolb Engineers**
- HVAC Design-Assist and Construction - Superior Air Handling
- Medical Gases Design-Assist and Construction - **L.J. Kruse Company**
- Plumbing Design-Assist & Construction - J.W. McClenahan
- Electrical Design-Assist & Construction - **Redwood City Electric**
- Fire Protection Design-Assist & Construction - Transbay Fire Protection
- Structural Steel Design-Assist & Construction - Herrick Steel

It is worth noting that Herrick Steel, which is on the SMCCV job without being part of the IFOA team, is an IFOA member on this job. On the contrary, Ghafari Associates is also on board on this job, but without being an IFOA member.

Whereas Sutter moved away from the Eden district at Castro Valley, Alta Bates Summit Medical Center, is partially funding this project. ABSMC, a hospital comprised of three campuses (Alta Bates and Herrick campuses in Berkeley and Summit Campus in Oakland), is relatively successful and promoting high standards of healthcare delivery. In 1992, they joined the California Healthcare System (CHS), an affiliation that merged with Sutter Health in January 1996. ABSMC is now a Sutter Health Affiliate, but has a lot of influence in the decision-making process. As a symbol, their name is in the Owner's "bubble" of the IFOA contract first page. And from the interviewees' point of views, it seems like Sutter is putting a lot of effort in trying to appease the ABSMC employees and meet their expectations.

As for SMCCV, the project needs to get the approval of OSHPD and the county of Alameda. But in addition, they are under the scrutiny of the City of Oakland, which lengthened the entitlement process.

[11] The players that were not on board at Castro Valley are in boldface.

For further information, contact Glenn Ballard, ballard@ce.berkeley.edu

5.1.3 Contractual structure

As on SMCCV, the Integrated Form of Agreement (IFOA) was used on this job, binding together the 12 IFOA partners cited earlier. The team members signed the EMP at the beginning of construction, and that contract oversaw the preconstruction agreement that was signed after validation.

5.1.4 Project timeline

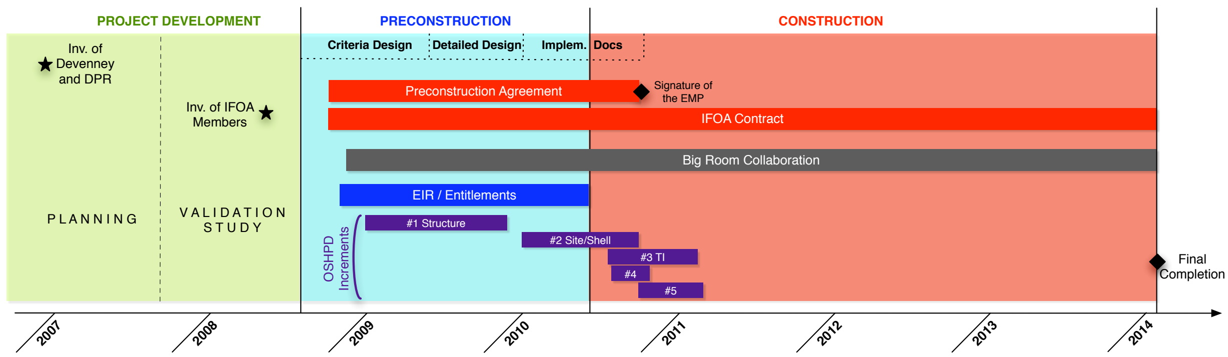

Figure 12: Project Timeline on ABSMC

The project timeline is also similar to SMCCV. By looking solely at the beginning of preconstruction and construction dates, the ABSMC project is following SMCCV with a 1-year lag. DPR and Devenney came on board almost at the same time on both projects though. The main difference time wise is the validation study that took about a year to be completed on ABSMC, instead of 6 weeks on SMCCV.

5.2 Implementation of TVD

Figure 13 is a process map of the TVD implementation, showing the primary area of influence of the owner, designers and contractors.

This map is voluntarily almost identical to the one for SMCCV, as the same "roadmap" of TVD implementation was followed. It is worth highlighting here the fact that the clinical program was not as set as on SMCCV during the validation study, and that users requests played a considerable role in influencing the values definition and VE process. In the following sections, the implementation of TVD is discussed in more details and contrasted to SMCCV, following the same analytical framework described in section 3.3.

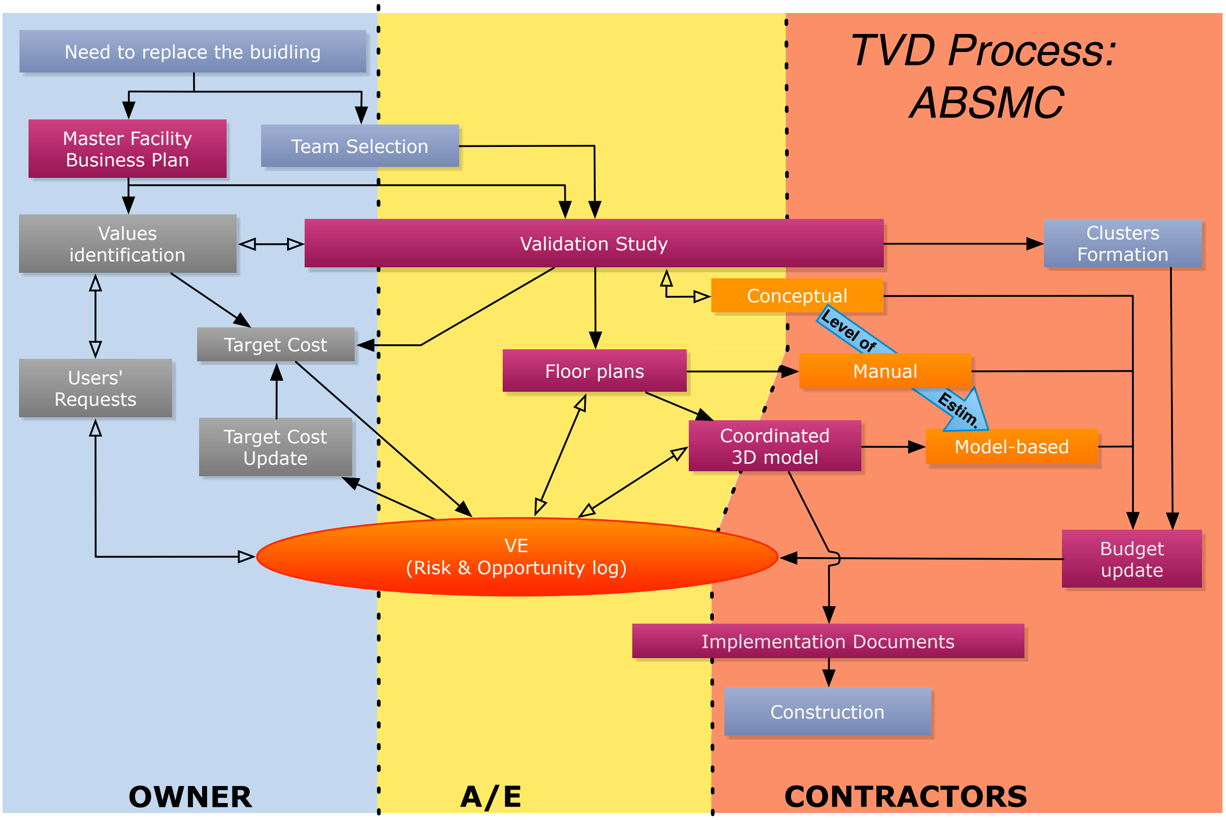

Figure 13: Target Value Design implementation on the ABSMC project

5.2.1 Organizing (preparing mechanisms for…)

5.2.1.1 Commercial terms & interests alignment:

As for SMCCV, the contractual environment on this job keeps the interests of IFOA members during the whole duration of the project. During preconstruction, the team worked together to get the Expected Cost down to an acceptable level. At the beginning of construction the IFOA members signed the EMP, putting their whole profit at risk following a risk and reward approach (or Painshare/Gainshare).

Figure 14 illustrates the Fee Pool calculation that was described in section 4.1.3. Through negotiation, the IFOA members agree on their respective overhead and profit markup for the Design/Preconstruction and CA/Construction phases. From those numbers, the expected profits of each team member are calculated, as well as the splits (in percentage) of the Fee Pool amounts (Sutter Health, 2010: appendix M). The summation of the individual expected profit gives the total expected profit, which corresponds to the profit markup the team will get if they managed to deliver the building for the EMP. On July 12, 2010, the EMP was set at $227,006,112. It is worth noting that this number may be adjusted for approved change orders, and as a result. Consequently, the expected profit of each team member, determined by multiplying its profit markup times its estimated Cost of Work, might fluctuate as well.

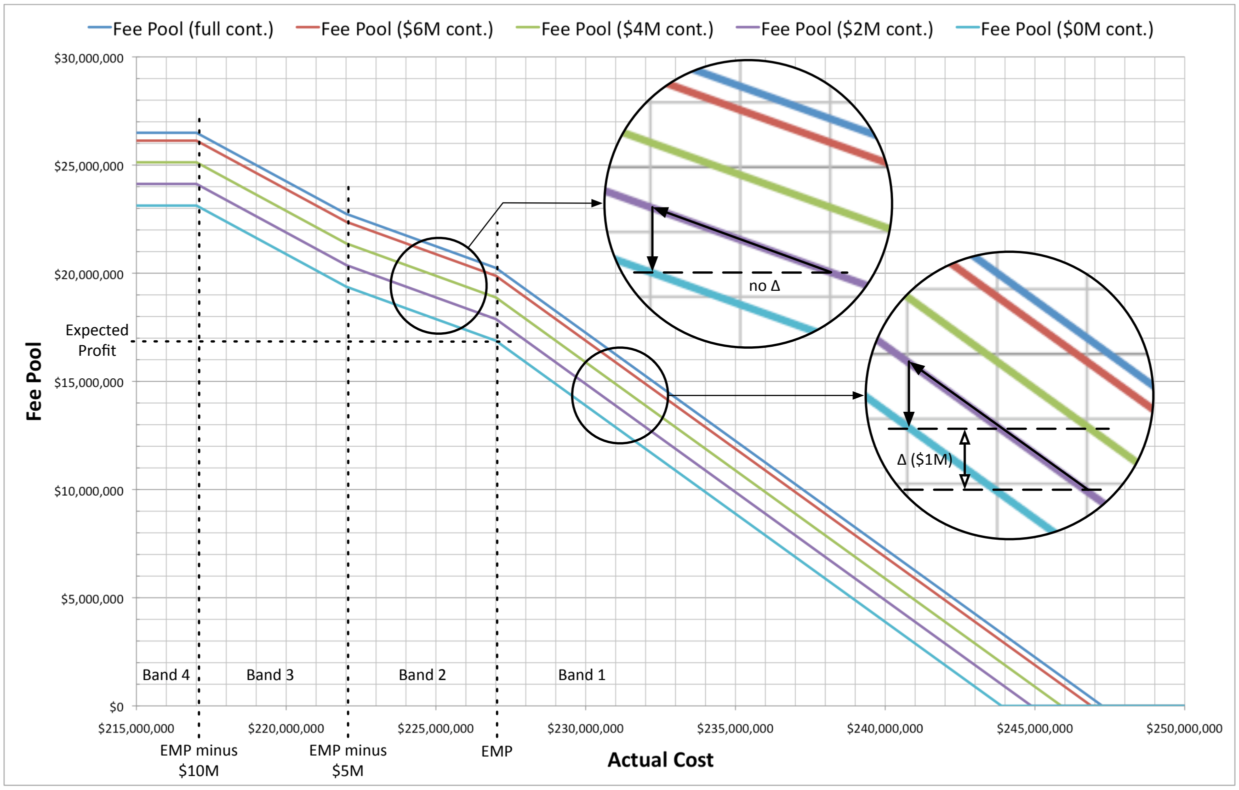

Figure 14: Fee Pool calculation based on the Actual Cost and IPD Contingency

Therefore, this chart represents the Fee Pool amount that will get shared by the team at the end of the job, supposing that the EMP stays identical. The Fee Pool amount depends on 2 parameters: the Actual Cost and the IPD Team Contingency unspent at time of Final Payment[12]. The Actual Cost of the Project determines the Band in which the IFOA team falls, as described in section 4.1.3. As put in evidence on Figure 14, the team bears all the risk of cost overruns (Band 1), but the Fee Pool can't be negative, meaning that cost of work and corresponding overhead are guaranteed by the Owner. If the IFOA team manages to deliver the project for less than the EMP, savings will be shared with the Owner, according to the Band within the Actual Cost falls.

On top of that, 50% of the IPD Team Contingency unspent at the time of Final Payment gets added to the Fee Pool, without regard to where the Actual Cost stands in comparison to the EMP. This system may lead to some tensions (already mentioned in section 3.2.2.4) that are put in evidence by the magnified areas on the graph. If the team is over budget, they have the incentive to use money from the IPD Team Contingency to pay for their cost overruns. If they use 2 million dollars from the IPD Team contingency bucket, their Actual Cost would decrease by 2 million dollars, resulting in a 1 million dollars addition to the Fee Pool (2 million dollars from the change in the Actual Cost minus 1 million dollars from the change in the IPD Team Contingency). This "gap" doesn't exist if the Actual Cost falls in Band 2, as the savings get evenly shared between the Owner and the IFOA team, just like the IPD Team Contingency unspent at

[12] The design team's and Owner's incentives under the PG&E Saving by Design program were not included in the calculations to avoid overloading the graph.

time of final payment. The way the IFOA team manages contingencies is further discussed in section 5.2.2.4.

Even if costs and overhead are guaranteed, having 100% profit at risk was something relatively new for some designers, who are not used to take that amount of risk. Depending on the size of the company, some of them would have felt more comfortable with having only a portion of the profit at risk, an approach taken on other Sutter projects such as California Pacific Medical Center's Cathedral Hill Campus.

After validation, the designers were billing their time at their normal rates, which included profit markup, until the EMP was signed. But the team at that time didn't think it would take so much time to negotiate the contract. And so designers were paid almost 2 years of profit during preconstruction, even though this money was supposed to be at risk as part of the Fee Pool. The consultants had to pay all that profit back to Sutter. Until April 2011, they were essentially billing their time without getting paid for it, as profit was taken out against future billings.

The fact that the IFOA contract (or EMP) was signed later than expected is partly the result of tensions around the EMP negotiation process. In regard to the timeline, the EMP was signed a little later on ABSMC than on SMCCV. Even throughout the first semester of 2010, a lot of changes happened and there wasn't enough certainty for the IFOA members to reach an agreement. They couldn't commit to a number, as the risk to lose profit was too important. This situation wasn't optimal, because up until the moment the EMP was signed, the team partners didn't care too much when the owner was changing their mind, as it was not "their money" yet. This is further discussed in section 5.2.2.2.

When it was time to sign the EMP, the IFOA team was still $6,500,000 over budget. Each subcontractor met with DPR and agreed to some concessions in their overhead and profit numbers, and increased some of their productivity rates, which ultimately filled the gap and led to an agreement. This process seemed to have generated frustration for some contractors, as they felt like they were required to carry more risk and make more concessions than other team members. However, everyone had the opportunity to refuse the deal and get out of the job. The fact that everyone signed it also means in a way that everyone was satisfied with the terms. Some of the initial overhead and profit numbers may have been a little too aggressive or not in line with the current market conditions.

In comparison to SMCCV, it seems like IFOA members had different levels of commitment to TVD. When the budget was tracked by cluster, some team members were really working on the numbers, while others were being more passive. Some companies may be hidden in these clusters and don't have the incentive to give their best efforts. At some point, DPR shifted from cluster targets to individual targets and started tracking the budget by company. It reflects a lack of accountability of some team members and questions the effectiveness of the incentives alignment approach.

As on SMCCV, managing and motivating non-IFOA members was challenging. Devenney alone had 15 design consultants that were not part of the IFOA team and didn't have any financial incentive to contain costs. Alta Bates selected the interior designers, who were put under Devenney. And a lot of times, Alta Bates was relying on the interior designers' point of view for approving or refusing change propositions. But they were not incentivized to reduce the budget, since they wanted to keep the architectural flare, while getting paid for their billed hours. There was no real interest alignment between the IFOA team members and such project actors. Also, even if Alta Bates is co-financing the project, they don't have as much incentive to contain the costs as Sutter does. This situation on the customer's end made the application of TVD on this project quite challenging, as discussed in section 5.2.2.2.

This discussion also raises the question of who should be included in the IFOA. On this job, anyone who controlled a certain amount of the budget was given the opportunity to join the IFOA. Other criteria, such as the amount of risk that a company manages or the extent to which they can provide useful input to the team, should be considered too. Compared to SMCCV, Herrick Steel was part of the IFOA team, which was a good thing according to the interviewees. Other companies, such as the glazing contractor or the interior designers, could also have brought some value by being an IFOA member. It should be kept in mind that if given the opportunity, some companies might not want to be part of the IFOA for a variety of reasons. For instance, they might prefer to carry the risk themselves (with a Lump Sum contract), or might not be willing to share their cost numbers.

5.2.1.2 Integrated team

Sutter and Alta Bates were part of the IFOA team and played a major role in this project. However, as highlighted by the results of the survey[13], they didn't participated as actively in the process as on SMCCV. This perception probably comes from the fact that the decision-making process on the owner's side was a little more "chaotic". As already mentioned, Alta Bates is co-financing the project and has a lot of influence, which enables the different user groups to express their desires. This resulted in a lot of changes and a lengthened decision-making process. Those difficulties were maybe aggravated by a lack of strong leadership.

As at Castro Valley, the key contractors were involved early on during validation, which enabled cost and constructability inputs from the beginning. As on SMCCV, the team made the decision to be partially co-located, first in Castro Valley and eventually on site since mid-2010. At the peak of design, most IFOA members had someone from their office almost every day at the trailer.

According to some interviewees, the team could maybe have done a better job at bringing the different subcontractors and consultants on board at the right time. Many non-IFOA members got involved relatively early on, as part of the scheme to get input from most players. However, if such players have a limited scope of work and do not bring value to the team through collaboration, they should rather be brought on board at the end of preconstruction, which may save design hours and reduce costs through hard bidding.

Every 2 weeks, the whole team gets together for the Big Room meetings. They would generally have a couple of hours of meeting all together, internal meetings in cluster setting and some report-out with everyone at the end. But during some sessions, the themes being discussed were only involving a handful of persons in the room, and many people in the room tended to work on something else on their laptop. Some managers were coming from far and these unproductive meetings led to a lot of frustration. It seems like the team could have done a better job at breaking out some of those Big Room meetings into cluster work sessions.

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[13] For component 6 of the TVD benchmark ("The customer is an active and permanent member of the project delivery team."), ABSMC received a score of 3.7, whereas SMCCV and UCSF respectively received 4.8 and 4.2.

For further information, contact Glenn Ballard, ballard@ce.berkeley.edu

5.2.1.3 Integrated Governance

cf. section 4.2.1.3

5.2.1.4 Joint responsibility, transparency

cf. section 4.2.1.4

5.2.1.5 Functional interface

Since validation the team is integrated, and design solutions are developed with cost, schedule and constructability inputs from the contractors. The IFOA members were given the opportunity to collaborate and interact easily if they had any question. It seems though that some negative design iterations could have been avoided. A lot of times, contractors would actually wait until they saw the final design to price it, to realize after-the-fact that it was too expensive and that everything should be redesigned. The structural engineer gave the example of concrete curbs that were used to support all the expansion and seismic joints. After the design got submitted to OSHPD, someone decided that they should be in steel instead of concrete, and they are now in a redesign cycle to change all the curbs design. Progress drawings were posted on ProjectWise, and everyone was invited to comment on those. But they were not looked at to a very detailed degree, and a lot of times, the contractors would not really look at the design until it was done. This mentality contributed to some design changes because of cost or constructability issues that could have been identified earlier on. Also, contractors are generally involving a different set of people for construction. Consequently, some constructability issues might be indentified by field people a long time after being initially designed.

5.2.2 Defining (ends & constraints)

5.2.2.1 Business Case

Because of the seismic requirements, the hospital had engaged for several years a team to retrofit the building. But this option proved to be too expensive, as it required patient displacements. Sutter engaged a new architect, Devenney, which came up with the idea to build a new patient tower. Sutter looked at the hospital Master Facility Business Plan, that justify expected revenues based on existing facilities. A certain amount of money had been allotted to this campus for seismic compliance, and Sutter judged that the project was feasible enough to engage a team to do a validation study.

As on SMCCV, the business case was really not the driver, and was not shared with the team. Since they were not building a brand new hospital, they didn't take many ideas from the "Prototype Hospital Initiative Report", and they had to tie the new tower into all existing services. During project development, the program and square footage never really settled down, and there were some misunderstandings from the standpoint of what "mother Sutter" thought they approved versus what the team was locally designing. The project got bigger and bigger (cf. figure 18), but was eventually approved.

5.2.2.2 Stakeholders values

The big difference with SMCCV is that the project team on ABSMC has to meet the expectations of both Sutter and its affiliate, Alta Bates. The latter really had the right to interject on the type of facility that was being delivered to them by Sutter. Within Alta Bates, the administrators understand the budget constraints and their interests are relatively aligned with Sutter. However, the end users (nurses, doctors, surgeons, etc.) had a lot of control in the decision-making process, without any incentive to contain costs.

Throughout project development, the patient tower was progressively designed narrower, taller and with more space. Consequently the price of the building also went up, which led to numerous meetings between the delivery team and the customers. The team helped the client realize that they were getting more value and a facility that could accommodate for their clinical program.

After validation, the clinical program wasn't as locked as on SMCCV, which led to numerous owner-driven changes during the first year. As an example, the 2nd floor was initially an entire mechanical space to serve all the diagnostic treatments in the bottom 3 floors. After validation the owner decided that they wanted to put dialysis and the pharmacy on that floor, reducing the mechanical space from 20,000 sq. ft. to 5,000 sq. ft., because they wanted to add more program. As a result, the mechanical engineers needed to displace equipment on the rooftop section of the building, causing interferences with the existing building. Such program changes led to substantial design rework and some frustration among the team. In early 2010, most of the trades and design consultants went away for a couple of months to give time to the owner to make decisions about program changes. In a way, the design was proceeding quicker than the clients' ability to make their own decision. This design "pause" was probably a wise thing to do, but could maybe have happened sooner and helped save a lot of money in redesign fees.

Even tough the team had a good understanding of what was expected at validation, there were more changes than normally during preconstruction. Those changes were not only driven by Sutter and Alta Bates, but were rather the result of a combination of several factors: changes due to an incomplete design, changes due to the fire department, changes due to OSHPD and changes due to clashes. It would be interesting to study what was done to understand OSHPD's and the fire department's "values".

The influence of the end users contributed significantly to some of these changes, as illustrated by the mock-up room numerous revisions. The team built a typical patient room early during design, to get input from nurses and other end users. As of April 2011, this process had been going on for a couple of years and the team had built the 14th version of the mock-up. In addition to the cost of actually building the mock-up, those revisions caused a lot of design iterations and cost a significant amount of money in redesign fees. A request related to interior finishes may lead to a redesign of the MEP systems, which in turn may have structural implications. It seems surprising that the end users requests were not more "channeled" and that their comments were not addressed during a couple of rounds only. The end users might not have had enough initial input during validation phase.

The main area for improvement is probably the way the customer requests were managed. Most of the requests were channeled through Sutter and Devenney, with little or no input from the rest of the team. The changes were "imposed" to the team, and sometimes the rework in redesign effort was worth more than the value the client got from the change. In that respect, the team was following the traditional process of addressing the user request, redesigning, costing the change and then realizing it was not a good decision. It seems like the team could have done a better job at helping the owner making more informed decisions. Through the A3 program, the team tried to follow a set-based design approach, exploring several design alternatives and their cost implications (cf. section 5.2.3.4). But a lot of times, the design changes were made first, without doing an A3. In a TVD setting, the integrated team should really help the owner make the right decisions, and transform the design-chain from a reactive to a proactive approach. And on this job, it seems that the changes could have been better documented and presented to the client.

Different systems or components of the facility were differently affected by user requests. Nobody really argues with what the structural engineer decided, especially in such a seismic region. The end users don't really care about what is behind the walls, as long it gives them the expected quality. But they want a nice-looking building and won't sacrifice the skin or the interiors. Therefore, the team had less room for innovation on some systems, making TVD more challenging. On SMCCV, the client had more "appetite" on the money side, and the team was able to sacrifice some of the interior finishes. They were not given this opportunity on this job, as Alta Bates and its interior designer had particularly strong expectations.

More generally, this job presented less opportunity for value engineering than SMCCV. A lot of changes that were proposed to the client were not accepted, even though they were above and beyond minimal code requirements, standards for healthcare and in accordance with the basis of design. Sutter would approve them, but Alta Bates would often times reject those changes, because they felt they were getting less value. It seems that there was not enough communication about the level of quality the users were expecting at the validation stage, or that the basis of design wasn't detailed enough. Some items that were requested by the users but not in the original budget drove the cost up and made it hard to reach targets.

To conclude, there is an opportunity here to improve the management of client requests. Sutter could have done a better job at setting the clinical program earlier on and channeling requests through a well-defined process from the beginning. Alta Bates could have imposed clearer deadlines to the end users for feedback on the design. And the rest of the team could have better documented and presented the changes that the client desired.

5.2.2.3 Plan validation

The validation (or feasibility) study took place between August 2007 and August 2008, thus lasting a whole year. This process was longer and more laborious than on SMCCV, as the program was not as locked at the time. It was more of a concept stage, and the team helped the owner shape the building, which eventually got narrower, more spacious and taller.

During the validation, Sutter had already assembled the team, which was working in a Big Room setting. Based on blocking and stacking diagrams developed by Devenney, the contractors were providing conceptual budget estimates. In the meantime, designers were validating the budget assumptions and discussing system approaches. As an example, Degenkolb, the structural engineer of record, looked at 3 structural systems (concrete shear walls, braced frames and steel moment frames) that were passed on to DPR for pricing. As on SMCCV, the team wrote up a design narrative (basis of design and basis of estimate) to describe what the budget was based upon. And Sutter was always in the room to help define the program.

As already mentioned, for some scope of work, there had been a mismatches between what the affiliates were expecting and what was meant in the basis of design:

> *"When we presented our basis of design document, there are certain things at that phase that, just per sake of not listing out every single thing and producing incomplete set of specifications, you really have to leave vague… For example, things like BAS (Building Automation System), "We are gonna provide you with a simple,*

> *efficient, user-friendly interface". What does that mean? A lot of interpretations are possible. To the facility's guy, who has to live with that for the rest of his life, what it means is: he wants a weather monitoring station, he wants something that measures all the gpm (gallons per minute) that is used in the sprinkler system in front of the building. And to us, that was a frivolous thing that you would never ask for." (A contractor)*

The budget narrative can sometimes be interpreted in different ways, which led on this job to scope additions, whereas the team was trying to reduce the budget. To avoid this particular problem, the basis of design/estimate could be more exhaustive, but the contractors might have trouble getting in too much detail, as the systems are not fully defined at that point in time. Furthermore, this mindset is contrary to the TVD philosophy that seeks to promote collaboration and common understanding rather than adversarial behaviors. Instead of shielding himself behind an exhaustive basis of estimate, the contractor should have more discussions with the users upfront to better understand the expected quality level. There should be nonetheless clear mechanisms to prevent the customer from asking for more while the targets stay the same.

5.2.2.4 Target setting

During validation, the team developed an overall conceptual budget based on the program. This budget (276 million dollars, excluding owner costs) was approved by the client and became the "target value" for the delivery team. This number changed over time due to scope movements, and in early 2009, since the entire project was over budget, the whole team agreed upon a target cost reduction of 8 million dollars. This target reduction was then passed on to the cluster. And in July 2010, the EMP became the formal target cost. As mentioned earlier, when the users were asking for more than what was in the basis of design/estimate, the target cost originally did not increase accordingly. But since the EMP was signed, scope removals and additions have to be formally approved by the Core Group.

Escalation and contingencies were handled the same way on this job as they were at Castro Valley. Based on input from everyone, the escalation was originally set around 18 million dollars, and became part of the contractors' individual budgets when the EMP was signed. At that time, the IPD Contingency was set at $6,731,585, and the Core Group solely controls the way it gets spent. It is agreed that the team shall draw on the contingency at a rate that is representative of the remaining risk on the job. Early on, the IPD Contingency was left untouched to keep people incentivized to minimize cost. Consequently, everything is being reported as cost overruns, therefore reducing the fee poll and the regular fee payments based on it.

To keep track of how each IFOA partner's cash flows perform relatively to the EMP, a marker program was instituted. In case of cost overruns, the contractor has to identify items where the cost was not anticipated based the resource-loaded work plan and relate those items to a marker. For each marker, which is basically a risk or an opportunity to the EMP baseline budget, each IFOA member specifies how its budget is impacted. When the time comes, the Core Group goes through the marker log and decides if money should be drawn out of the IPD Contingency or the Owner Contingency to pay for a specific marker. If so, the item gets labeled as an approved Change Order, and the EMP and contingency buckets get updated accordingly.

5.2.3 Steering (means)

5.2.3.1 Cross-functional teams

As on SMCCV, the IFOA team was organized in clusters, which structured the budgeting and value engineering efforts. Since early 2009, the budget has been broken down according to the following clusters:

- PRE (Preconstruction)
- CA (Construction Administration)
- INT (Interior)
- STR (Structure)
- MEP (Mechanical, Electrical, Plumbing and Fire Protection)
- EXT (Exterior)
- SITE (Sitework)
- COM (Communication)
- FFE (Furniture, Furnishings & Equipment)
- OWN (Owner)

A target cost reduction of 6.5% was assigned to each cluster, which had to collaboratively find ways to reach this target while reporting progress twice a month. These targets didn't necessarily make a lot of sense as different disciplines offer various degrees of opportunities for value engineering. In addition, there have been a lot of scope movements across cluster boundaries, and there were duplications of budget items and some confusion around what was actually included in each cluster. And when money got moved around, the targets were not systematically changed accordingly. It was therefore hard to assess the progress of each cluster towards its target. Also, within a cluster, each company was not equally contributing to the TVD effort. Different companies may not have the same leeway. In addition, when combined in such big buckets, certain companies were not as motivated as others (cf. section 5.2.1.1). Consequently, the team eventually made the decision to track the budget by company rather than by cluster, in order to make the team partners more accountable. These considerations raise the question of the best system to incentivize the TVD effort. Even though individuals are not solely motivated by financial incentives, it is important to provide some sort of recognition for active participation, which the cluster organization attempts to do.

Besides their budget reporting function, clusters also fostered collaboration and integration between designers and contractors, but also across disciplines. Brainstorming sessions were held regularly as part of the value engineering effort. Initially, there was only one cluster lead, either from the contractor's or designer's side. At the beginning of 2010, the team decided to have two cluster leads (one from each side), because DPR's expertise in cost estimating was needed to drive the effort. It took some time to establish the appropriate management structure at the cluster level, since getting enough competent leads for each cluster was challenging.

5.2.3.2 Design planning

As on SMCCV, the design was submitted to OSHPD through Phased Plan Review (PPR). The increments, driven by the seismic requirements, were developed in collaboration between Sutter, Devenney and OSHPD. At some point, a draft was passed into the Big Room for comments on schedule, durations, how the increments were set up, and so forth. The final increments are very similar to the ones on SMCCV, except for the combination of site development and exterior enclosure into a single increment:

0. Geotechnical Report
1. Primary Structural
2. Site/Foundation & Shell
3. Interior Architecture Package
4. Seismic Anchorage

Because of the numerous changes on this project, the OSHPD deliverable dates were moving targets. Changes were interfering with the submittal schedule and sometimes led to design rework on already submitted segments. In several occasions, the team asked OSHPD for more time, and by doing so, they were able to actually coordinate their work to a higher degree of certainty before turning it in.

The team then worked the way back from the submittal dates by doing pull scheduling and developed a main schedule in primavera. When it came to planning, the team worked collaboratively on every different line of the main schedule through Value Stream Mapping on the wall. Like on SMCCV, the SPS system was brought on board to facilitate the collaborative design planning process. Under the supervision of Ghafari, a lot of time was spent designing processes, setting interdependencies between activities, identifying last responsible moments and understanding the sequencing of activities. According to many interviewees, this process was a pretty extensive effort, and it might be worth studying its benefits. Three times a week, the concerned actors do accountability calls during which they identify which tasks were completed, which ones were not and the cause for non-completion (resource constrained, effort underestimation, and so forth). Some kind of pressure came from those accountability calls, as nobody wants to be held responsible.

5.2.3.3 Cost modeling

As on Castro Valley, they had a 2-week cycle for the budget updates and the coordination process. Every Thursday, designers would lock their design; the modelers would pick up the new drawings and update the 3D model, and contractors would conduct clash detections and price the new design. As emphasized by the survey[14] though, the collaboration between designers and contractors was maybe not as intimate and cost feedbacks came more after-the-fact than on SMCCV. The tools used for 3D modeling and cost estimating as well as the overall estimating process were identical to SMCCV (cf. section 4.2.3.3 and more particularly table 5 and figure 7). The main divergences are presented here.

With the exception of **interior finishes**, most of the job was modeled in 3D. Devenney modeled the **architectural** elements in a Revit model, which was used by DPR for estimating. For other trades, the modeling process was not as “integrated”. When Carmel Sales came on board in December 2008, they didn’t have time to do any 3D modeling because they were not expert at it and the OSHPD deadline was in 6 months. Devenney did the 3D modeling for the **exteriors**, which turned out to be less effective, and Carmel Sales eventually modeled the Unistack system for coordination purposes after the OSHPD package went it. Degenkolb modeled the **structure** in Revit, but Herrick Steel decided to build its own 3D model in Tekla from scratch, because it was needed for estimating. Ainsworth Associates, the

[14] The 11th component of the TVD benchmark (Cost estimating and budgeting is done continuously through intimate collaboration between members of the project team—‘over the shoulder estimating’) received a score of 3.1 on ABSMC and 4.1 on SMCCV.

mechanical designer, didn't draw in 3D, because they had no experience with CAD-Duct and CAD-Pipe. The mechanical contractors, J.W. McClenahan and Superior Air Handling, did their 3D modeling based on 2D drawings from the engineers. This approach can be appropriate, since contractors are more knowledgeable about the way piping and ductwork get manufactured and installed on the field. However, when the contractors changed things in coordination because of routing or offsets, the engineers had to redo their 2D drawings based on the 3D model, in order to provide a coordinated set of drawings to OSHPD. It caused a lot of rework and some of the submitted drawings eventually didn't match the coordinated model. In the future, it would be beneficial to overcome those software compatibility problems and push designers and contractors of a same trade to work on the same platform. Designers might have to spend some time learning how the contractors would like to see the elements modeled, but working on a single model should eventually save a lot of time and avoid mismatches between different models.

Just before the EMP was signed, less than a third of the job was estimated directly from the model[15]. As on SMCCV, the estimating process still relied heavily on traditional estimating for most of the trades. The same areas for improvement apply to this project:

1. Sharpen the initial setup and facilitate transitions
2. Model more
3. Use the model more effectively
4. Automate the information flow

To expand on that, the HVAC contractor reported that the transitions from an estimating method to another were challenging. They had trouble knowing when the design was complete enough to do takeoffs or how to carry certain items in the budget. Another difficult transition was pulling out data from the model and matching it from a set of plans that their estimators had finished by hands. As mentioned earlier, they were drawing in 3D based on 2D drawings from Ainsworth Associates, which led to a lot of back and forth. Even when they had a 3D model in CAD-Duct, they kept doing manual quantity takeoffs. The primary purpose of the 3D model was clash detections and the production of shop drawings. When doing manual quantity takeoffs, the estimator is using a digitizer table with an estimating program (QuickPen). Thus, the estimates were done with a different program than the one they use to model with. They used the quantities coming from the model, but only to validate what they took off manually. This example illustrates well the opportunities to improve the cost estimating process in the future.

The cost information data was assembled manually in Timberline to update the budget reports every 2 weeks. At the cluster level, someone from DPR was initially responsible for collecting the estimates, and passing the information to the main estimator, who would check it and put together the budget at the project level. For DPR, there was a balance to find between letting every company report their numbers and controlling the budget reporting process:

> *"And it almost came to a point where there were too many people touching it and looking at it and cutting and pasting from one spreadsheet to another. And in the end, you would look at that number and you didn't even know if it was yours anymore. Does it include escalation? Does it have my profit in? Is my overhead separate? And there was a lot of confusion about that." (A contractor)*

[15] As of June 23, 2010, 27% of the EMP Estimate Source was model-based, while 69% and 4% were respectively traditional and conceptual based estimates.

So at some point, DPR required each company to fill out themselves a single spreadsheet in a standardized format (labor, material, equipment, exterior work, administration, escalation, etc.). There was no more intermediary, and DPR was simply checking the numbers to make sure they were consistent. On this job, the cost assembly process was initially pretty laborious, and the team lost track of the budget several times: some line items and documents were lost and they had to redo everything. The clusters apparently brought some confusion, as scope kept moving from one cluster to another. Changing the cost assembly process helped organizing the budget. However, the team also learned that they have to change it the least amount of times possible, because it just increases the chances for mistake and misunderstanding.

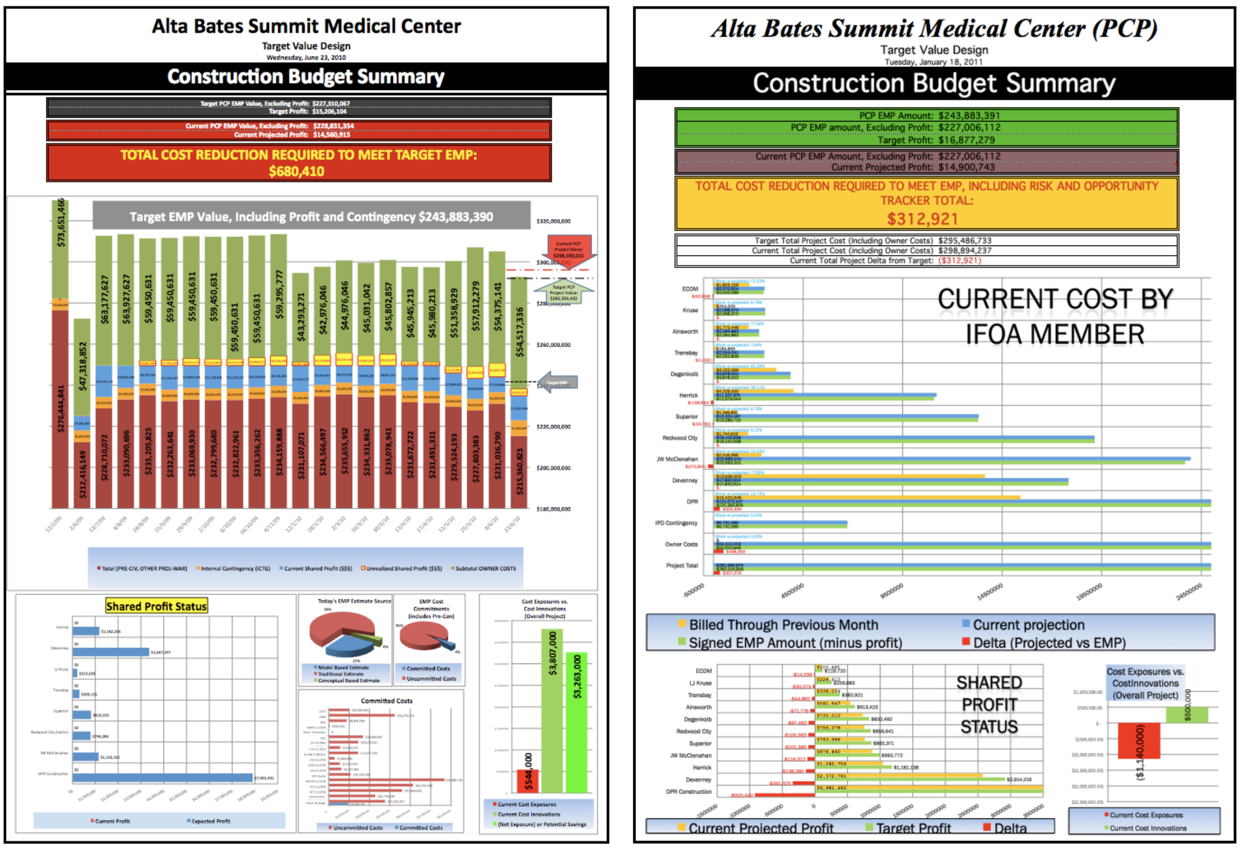


Figure 15: Budget Reporting on ABSMC: before[16] (left) and after[17] (right) the signature of the EMP

The team developed similar budget reports than on SMCCV, which combined the clusters budget information, the risk & opportunity log and a budget chart. The latter acquainted the team with major budget indicators, which was helpful to inform them quickly about where the project was going financially. As shown on figure 15, this one-page summary's presentation changed once the EMP was signed. The format was initially very similar to the one at Castro Valley. But to make each company more

[16] This budget chart is taken from the 06/23/2010 Budget Report.

[17] This budget chart is taken from the 01/18/2011 Budget Report.

accountable (cf. section 5.2.1.1), DPR decided to track the budget by IFOA member, rather than by company.

If possible, the team should try to be consistent and answer those questions at the beginning:

- How will the estimates be done? Which software will be used?
- How will the cost data be assembled?
- How will the budget be reported?

When processes change along the way, people tend to be lost and it increases chances of error and misunderstanding.

5.2.3.4 Analysis of alternatives

To some extent, designers had input from the contractors about cost, constructability and schedule before even developing their design alternatives. However, it seems that the team didn't achieve the same level of integration as on SMCCV and that the feedback from the contractors were mostly coming after-the-fact.

The team also used the Risk & Opportunity log to bring up any risk item or VE opportunity. The process, represented on figure 16, was very similar to the one on Castro Valley.

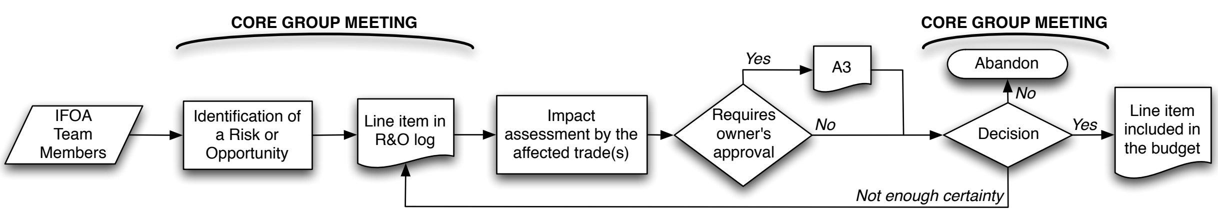


Figure 16: Risk & Opportunity log process on ABSMC

The main differences with SMCCV are:

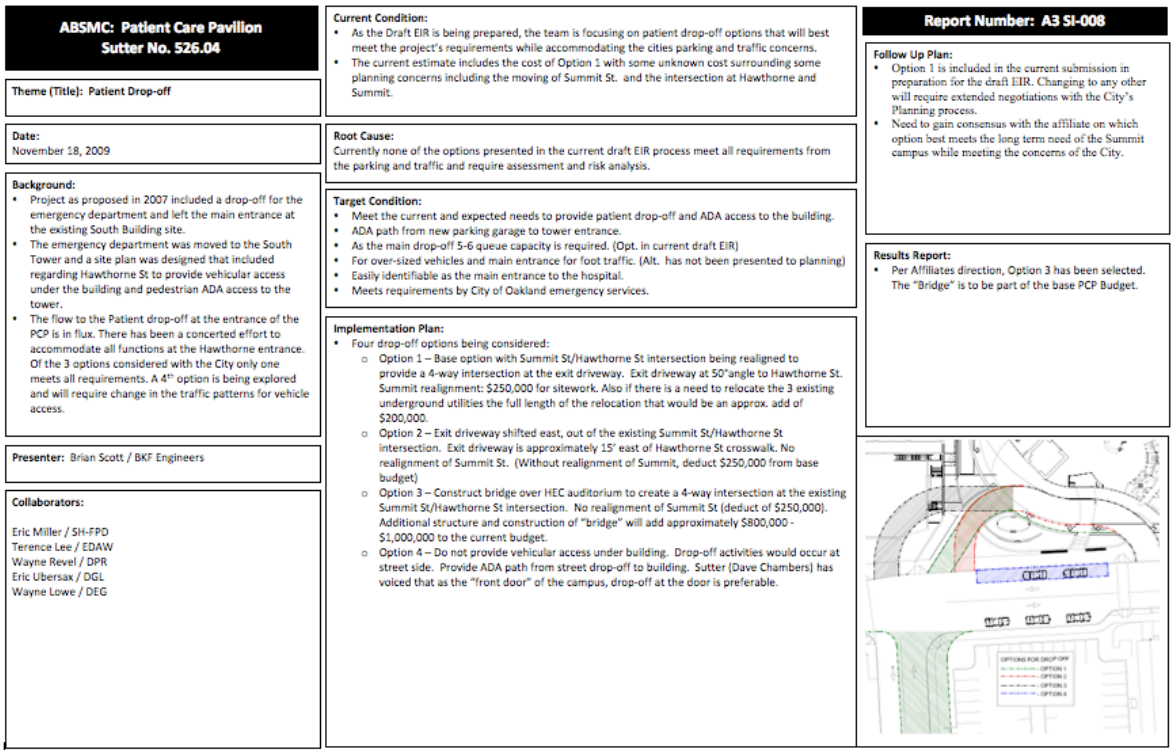
- No probability assessment was performed;
- They developed an A3 for any change in the design that required owner approval;
- It included owner driven Change Orders, until they were moved to the CO log.

A3s were oftentimes presented to the client to propose several design alternatives with their cost, schedule and quality implications. Figure 17 is an example of A3 Report. The term "A3"derives from the paper size originally used for the report, which is the metric equivalent to 11" by 17" paper. On this job, the A3 Process helped team partners engage in a collaborative, in-depth problem-solving approach to propose design changes. As put in evidence on the example in figure 17, the "traditional" steps of the A3 Process were followed, and for each change, the following paragraphs were to be completed:

1. Theme
2. Date
3. Background
4. Presenter and Collaborators
5. Current Condition
6. Root Cause
7. Target Condition

8. Implementation Plan
9. Follow-up plan
10. Results Report

The A3 Process has common ground with the set-based design approach, which consists of exploring different design alternatives in parallel and making a decision at the last responsible moment.



ABSMC: Patient Care Pavilion
Sutter No. 526.04

Theme (Title): Patient Drop-off

Date:
November 18, 2009

Background:
- Project as proposed in 2007 included a drop-off for the emergency department and left the main entrance at the existing South Building site.
- The emergency department was moved to the South Tower and a site plan was designed that included regarding Hawthorne St to provide vehicular access under the building and pedestrian ADA access to the tower.
- The flow to the Patient drop-off at the entrance of the PCP is in flux. There has been a concerted effort to accommodate all functions at the Hawthorne entrance. Of the 3 options considered with the City only one meets all requirements. A 4th option is being explored and will require change in the traffic patterns for vehicle access.

Presenter: Brian Scott / BKF Engineers

Collaborators:

Eric Miller / SH-FPD
Terence Lee / EDAW
Wayne Revel / DPR
Eric Ubersax / DGL
Wayne Lowe / DEG

Current Condition:
- As the Draft EIR is being prepared, the team is focusing on patient drop-off options that will best meet the project's requirements while accommodating the cities parking and traffic concerns.
- The current estimate includes the cost of Option 1 with some unknown cost surrounding some planning concerns including the moving of Summit St. and the intersection at Hawthorne and Summit.

Root Cause:
Currently none of the options presented in the current draft EIR process meet all requirements from the parking and traffic and require assessment and risk analysis.

Target Condition:
- Meet the current and expected needs to provide patient drop-off and ADA access to the building.
- ADA path from new parking garage to tower entrance.
- As the main drop-off 5-6 queue capacity is required. (Opt. in current draft EIR)
- For over-sized vehicles and main entrance for foot traffic. (Alt. has not been presented to planning)
- Easily identifiable as the main entrance to the hospital.
- Meets requirements by City of Oakland emergency services.

Implementation Plan:
- Four drop-off options being considered:
  - Option 1 – Base option with Summit St/Hawthorne St intersection being realigned to provide a 4-way intersection at the exit driveway. Exit driveway at 50°angle to Hawthorne St. Summit realignment: $250,000 for sitework. Also if there is a need to relocate the 3 existing underground utilities the full length of the relocation that would be an approx. add of $200,000.
  - Option 2 – Exit driveway shifted east, out of the existing Summit St/Hawthorne St intersection. Exit driveway is approximately 15' east of Hawthorne St crosswalk. No realignment of Summit St. (Without realignment of Summit, deduct $250,000 from base budget)
  - Option 3 – Construct bridge over HEC auditorium to create a 4-way intersection at the existing Summit St/Hawthorne St intersection. No realignment of Summit St (deduct of $250,000). Additional structure and construction of "bridge" will add approximately $800,000 - $1,000,000 to the current budget.
  - Option 4 – Do not provide vehicular access under building. Drop-off activities would occur at street side. Provide ADA path from street drop-off to building. Sutter (Dave Chambers) has voiced that as the "front door" of the campus, drop-off at the door is preferable.

Report Number: A3 SI-008

Follow Up Plan:
- Option 1 is included in the current submission in preparation for the draft EIR. Changing to any other will require extended negotiations with the City's Planning process.
- Need to gain consensus with the affiliate on which option best meets the long term need of the Summit campus while meeting the concerns of the City.

Results Report:
- Per Affiliates direction, Option 3 has been selected. The "Bridge" is to be part of the base PCP Budget.

Figure 17: Example of an A3 Report (Patient drop-off)

According to the interviewees, this process was a good way to keep the history of how the team got to a decision and it was extensively used on the job (approximately 75 A3s to date). Some changes were straightforward and didn't need an A3. But whenever the team identified a VE opportunity that differed from the basis of design or was facing a user request, they were supposed to develop an A3. However, there were also a lot of changes that would have deserved an A3 and didn't get one. At the beginning, some changes based on user requests were processed through the entire design-chain, until the client realized they couldn't afford it. The team eventually moved away from this traditional approach and started pursuing the A3 process before making any design change.

As already mentioned in section 5.2.2.2, finding acceptable VE ideas proved to be a little more challenging on this job. According to a contractor, *"a lot of innovations and ideas that were put forward were rejected by the affiliates, because they felt like it was value elimination instead of value engineering; because they felt like we were giving them inferior quality by changing things in the design."* This resistance from the affiliates made it more difficult to innovate.

5.3 Results

5.3.1 Budget evolution

Figure 18 shows the evolution of the budget from the beginning of the project development phase to this date. It displays the progress of the overall project Expected Cost towards toward the overall project Target Cost, as well as the progress of the projected Actual Cost (excluding Owner's costs) toward the projected EMP, once the latter had been signed.

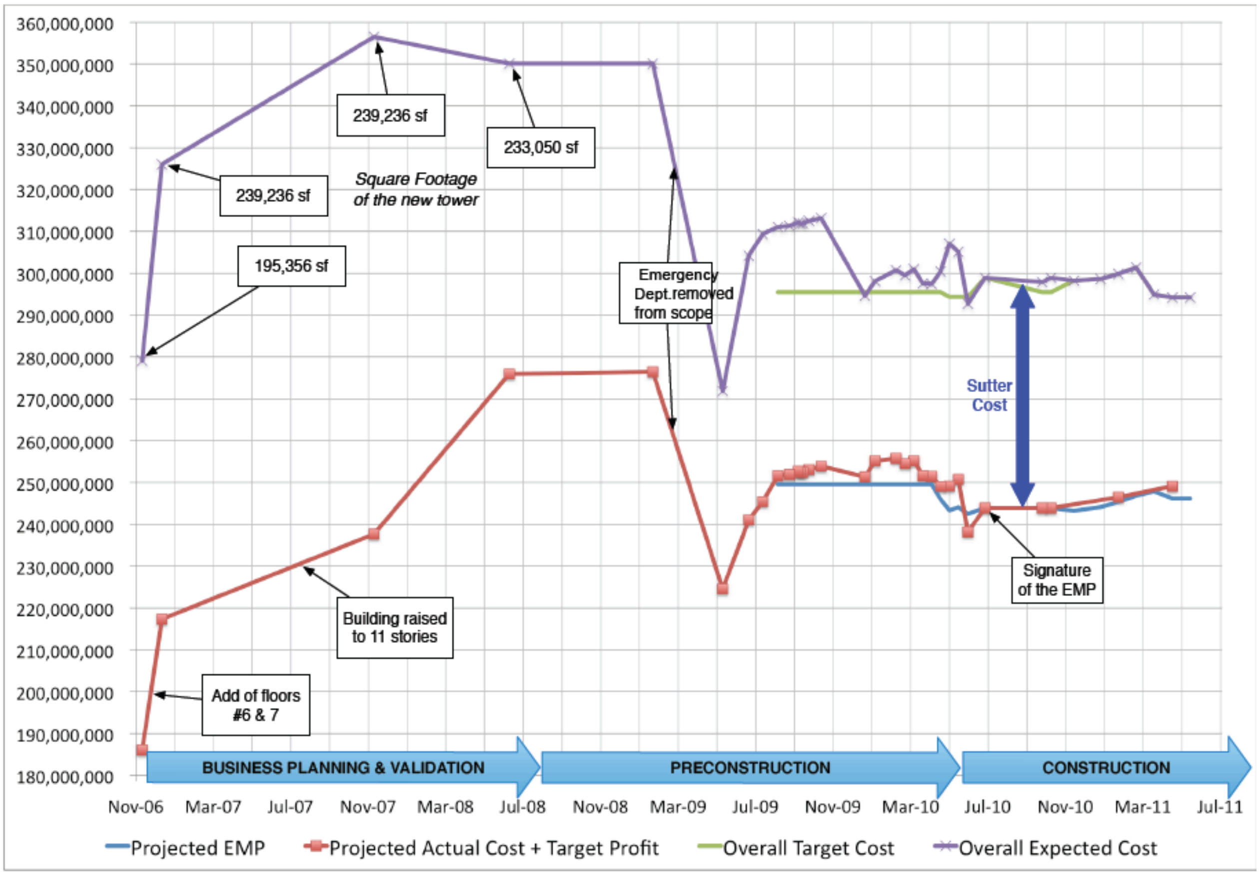


Figure 18: Budget evolution on ABSMC

The budget varied significantly during project development, as the patient tower got taller and more spacious. Even after validation, there were some scope changes, which make it hard to determine a cost reduction metric.

5.3.2 An innovative project?

Some innovations, like the ones on the curtain walls or the foundations, brought a lot of value. As an example, for the foundations, the structural engineers switched from CIDH (cast-in-drilled-holes) piles to Augercast piles. The latter method consists of injecting concrete under pressure, which prevents water intrusion into the hole. The production rate is also higher, and it requires less rebar than CIDH piles. This solution was explored on SMCCV, but rejected because it would have cost money in redesigning and may have delayed the approval process. On ABSMC, because the schedule was not as aggressive, the team did an A3 and decided to go with the Augercast system. But until OSHPD approved it, they ran both design alternatives in parallel for 18 months. It required approximately a quarter million dollars in redesign work and OSHPD re-permitting, but it eventually saved about two million dollars.

Otherwise, the MEP systems are relatively traditional. As for Castro Valley, this project was more innovative regarding its processes than the product by itself. Based on the interviews, it seems like this collaborative approach was less fruitfully implemented than on SMCCV:

> *"This process was a little bit different. I don't think it was as well organized from the DA standpoint as other IPD projects have been. But again, I don't know what drove a lot of the things too, whether it's the end user driving it, if it's problems with the way the whole process has been set up. You just don't know. But this one was just more broken than most." (A contractor)*

At this time, the project is still early into construction though. We should wait until project completion before drawing any conclusions on the outcomes of the TVD implementation.

6 UCSF Medical Center at Mission Bay

6.1 Project background

6.1.1 The product

The UCSF Medical Center at Mission Bay is a ground-up integrated hospital complex on its 57-acre biomedical campus, which will include:

- A 289-bed Children's, Women's and Cancer Hospital (Hospital);
- A 200,000-sq.-ft. Outpatient Building (OPB);
- A 46,000-sq.-ft. Energy Center (EC), helipad, parking and support services.

Figure 19: UCSF Medical Center at Mission Bay (UCSF Medical Center, 2010)

6.1.2 Different actors

The client is the University of California at San Francisco (UCSF), one of the world's leading centers of health sciences research, patient care, and education. UCSF Medical Center already includes 2 campuses located at Parnassus Heights and Mount Zion, and the third campus at Mission Bay will play a major role in the development of the organization. It is expected that, ultimately, the Hospital at the UCSF campus-Mission Bay location may expand to include a Hospital with up to 550 beds and appropriately sized outpatient building, an energy center and parking facilities (UCSF Medical Center, 2007).

The architect of record, ANSHEN+ALLEN, came on board in January 2007, and participated in the selection process of the other designers. The CM/Contractor, DPR Construction, as well as the MEP contractors were selected later during the Design Development Phase. Here are the main project actors:

- Owner – University of California, San Francisco
  - Project & Construction Management Consultant – Cambridge CM, Inc.
- Architect – ANSHEN+ALLEN, part of Stantec Architecture
  - Associate Architect – William McDonough + Partners
  - Structural Engineers – Rutherford & Cheken; Arup
  - MEP Engineers – Arup
  - Civil Engineer – CSW | Stuber Stroeh Engineering Group
  - Landscape Architect – EDAW AECOM

  - Communications – Teecom Design Group
- General Contractor – DPR Construction
  - Mechanical Contractors – ACCO Engineered Systems; Southland Industries
  - Electrical Contractors – Rosendin Electric; Redwood City Electric
  - Plumbing Contractors – Broadway Mechanical-Contractors, Inc.; Southland Industries

In 2007, UCSF was authorized to conduct a pilot program for "best value" contractor selection. DPR and the key subcontractors were procured through BVC/BVQ (Best Value Criteria and Best Value Questionnaire), a process similar to the RFQ/RFP (Request For Qualification and Request For Proposal) process. "Best Value" is defined as "a procurement process whereby the lowest responsible bidder may be selected on the basis of objective criteria with the resulting selection representing the best combination of price and qualification (UCSF Medical Center, 2008). "Qualifications" include:

1. Financial condition (bonding capacity).
2. Relevant experience (in cost modeling, continuous value engineering or DA contracts).
3. Demonstrated management competency.
4. Labor compliance
5. Safety record

The mechanical, electrical and plumbing packages were broken down between different companies, in order to mitigate the risk. For instance, the electrical for the Hospital and EC were allocated to Rosendin Electric, while Redwood City Electric is doing the OPB and all the sitework.

6.1.3 Contractual structure

The University is a public entity and thereof has to comply with specific contracting procedures. The UC system has many options for project delivery: design-build, cost-plus, and "construction manager" project delivery methods, although contracts must be advertised and awarded to the lowest responsible bidders. The public contracting code prevented the university from using a multi-party agreement. On this job, they have been striving to establish an integrated environment, without the contractual structure. To follow the AIA terminology, this job can be characterized as pursuing "IPD as a Philosophy" or being "IPD-ish", in contrast to "IPD as a Delivery Method", which implies the use of a multi-party agreement (AIA, 2010). IPD-ish is characterized by "traditional" transactional CM at-Risk or Design-Build contracts, some limited risk sharing, and some application of IPD principles.

ANSHEN+ALLEN has a conventional Owner-Architect contract with the University, while DPR has a CM at Risk Fixed Fee Cost Plus with GMP contract. The DA subcontractors had LS contracts during the design phase and were contracted under the GMP for construction. Because the job is so large, DPR had to split it in 2 bonds, as nobody had a sufficient bonding capacity.

With the GMP, there is some risk pooling, and the team adopted several IPD techniques and principles: involvement of key contractors during Design Development, procurement through Best Value, BIM utilization, co-location, Target Value Design, etc.

6.1.4 Project timeline

As previously mentioned, designers started getting on board at the beginning of 2007, about a year and a half before the contractors. As soon as the DA subcontractors came on board, the team started working in an ICDC (Integrated Center for Design and Construction) setting, similar to the level of co-location on SMCCV and ABSMC. The GMP was signed in November 2011, at the beginning of construction.

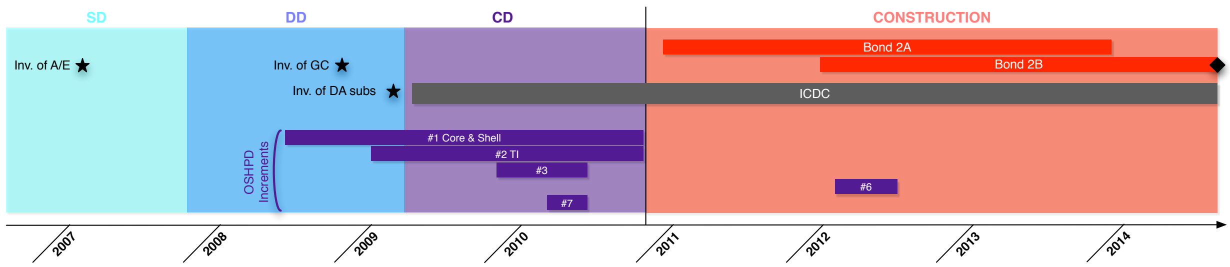


Figure 20: Project timeline on UCSF

As for the Sutter projects, the building permit is subject to OSHPD approval and the project schedule had to meet the SB 1953/SB 1661 deadlines. The submission of the design was broken down by increments, following the Phased Plan Review (PPR) approach already described in section 4.1.4.

6.2 Implementation of TVD

Target Value Design is a technique that is commonly pursued in an IPD-setting, but could also be adapted to other applications, such as proposal and bid development and Design-Build projects. The UCSF project gives us the opportunity to evaluate the success of TVD implementation without an IPD contract.

The term "Target Value Design" is not really used on this job, where people talk about Target Budget or Target GMP rather than Target Cost. As highlighted by the survey results, there is certain lack of consensus between team members regarding the application of the TVD benchmark on this job[18] (cf. table 3). But according to the same survey, this project received a "TVD score" of 69%, not so far behind ABSMC (75%).

Figure 21 is a process map of the TVD implementation, which shows who was primarily responsible for each process and document relevant to TVD. The time dimension has been kept, to stress that the different actors did not come on board at the same time. The following subsections present the mechanisms put in place to support TVD as well as the limitations, following the same framework as for the Sutter projects.

[18] Out of the 17 components, the standard deviation for each component's score was inferior than 1 for only 3 of them (compared to 15 for SMCCV and 13 for ABSMC).

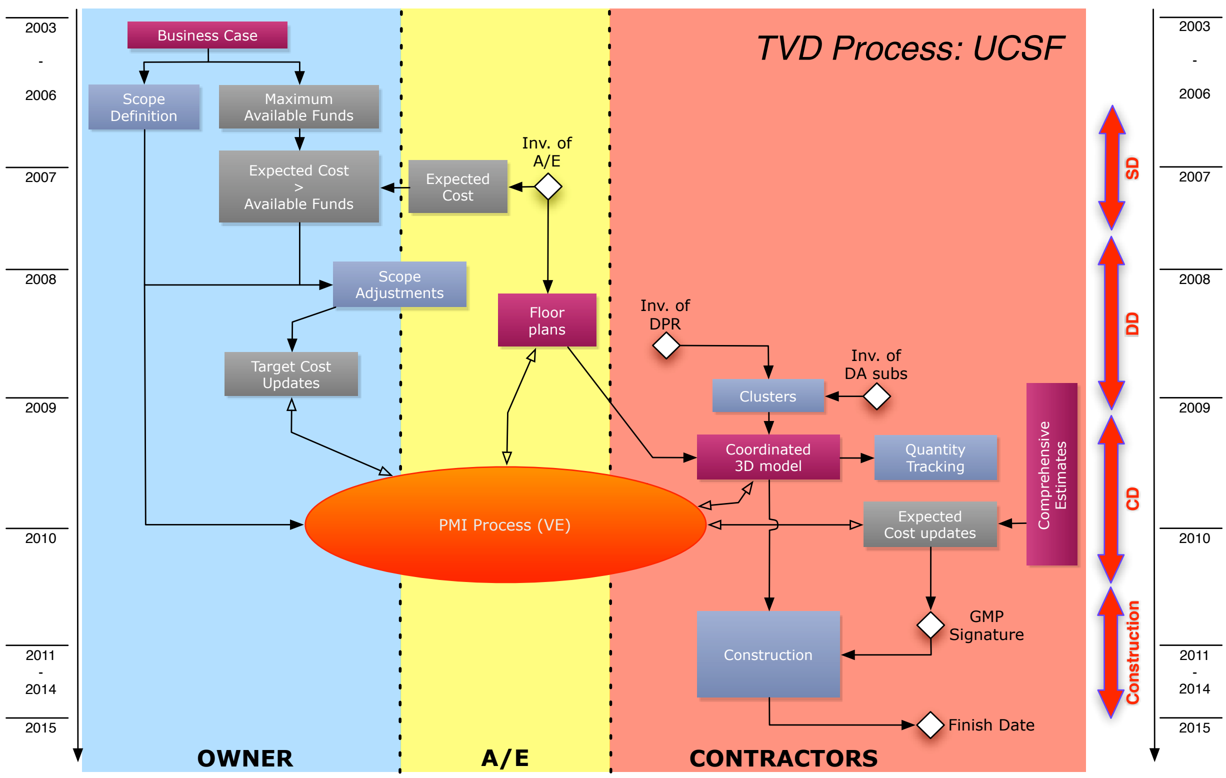


Figure 21: Target Value Design Implementation on UCSF

6.2.1 Organizing (preparing mechanisms for…)

6.2.1.1 Commercial terms & interests alignment

As for the Sutter projects, the distinction should be made between the preconstruction and construction phases, which are demarcated by the GMP signature.

During the design phase, it was in the shared interest of all team members to make the project financially viable. To actually build the project, everyone knew that they had to get the project down to the right number and the right scope.

Everyone had that in mind and was committed to working together and sharing goals. Even if the contractual terms were not supporting it, the project team behaved like this was an IPD project.

The Architect came on board in 2007. The project couldn't take advantage of some the opportunities of IPD; e.g., the alignment of interests between designer and builders was implicit, but not contractual. The did not share risk and reward with the contractors, as they would in a fully IPD project. Initially, they were not co-located, but that changed at the insistence of the client.

During construction, designers have separate cost plus contracts with the University. But the contractors signed in January 2011 a GMP with multiple incentives built in: risk pooling, but also schedule, safety, Last Planner® and limitation of Change Orders incentives. Within the overall GMP for construction, there are separate individual GMP's for the major subcontractors, which represent their costs and expected profit percentage at the time the EMP was signed (it may fluctuate due to owner-driven changes). The subcontractors fully take the risk of cost overruns, but share the savings. The first half of the savings goes back to UCSF, while the other half goes into a risk pool bucket that must satisfy some conditions before getting shared between everyone. The same risk and reward mechanisms also apply to DPR's GMP (the overall construction GMP). At first sight, this contractual agreement seems less attractive than Lump Sum contracts, since contractors are bearing the risk of cost overruns, while getting only a portion of the potential savings. However, thanks to the risk pooling, this contract incentivizes UCSF and each team partner to protect everyone else's interest. Knowing that the owner will "have your back" is precious on a job as large and complex as this one. Among the other incentives, the largest moneywise is the schedule incentive, which encourage the construction team to meet 27 milestones, approximately 9 per building. These various incentives contributed to align the interests of the construction team. It should be noted that as on ABSMC, the negotiation of the GMP terms took a long time and led to some tension between the owner and the contracting side.

6.2.1.2 Integrated Team

As highlighted by the survey, the University had been an active and permanent member of the project delivery team throughout the entire design phase[19]. The architect came on board in January 2007, followed a couple of months later by Arup and the main engineers. DPR got involved around mid-2009 (approximately 50% DD), and was busy engaging subcontractors during the first 6 months. In February 2009 (approximately 95% DD), the core DA subcontractors came on board, and the project delivery team essentially started operating as an integrated team from that point.

According to interviewees from both the contracting and designing sides, the contractors were probably involved a little too late to get the full benefit from this integrated team setting:

> *"We were brought on probably 6 months later than we should have been to be as effective as we could have been. Mainly because the target dates for submission to OSHPD had already been set. And so, what happened was that we weren't afforded the opportunity to (at least in the first go-round) look at VE methods and discuss them at length. It was very much a quick decision on whether or not it was buyable." (A DA subcontractor)*

Earlier involvement of contractors would have cost the owner more money initially and pushed everyone outside their comfort zones, as contractors are not used to big design iterations. But everyone agreed that there could have been more benefits to the owner if the contractors had come on board 6 months to a year earlier. It would have given everyone a little more time to get to know each other, build trust and structure the work. Contractors didn't have the opportunity to give cost and constructability input on the systems layout during SD phase. So when they came on board, the big design decisions were already taken and they didn't have enough time to fully discuss VE opportunity ideas before OSHPD submittals. If this had been a private sector project, contractors could have been involved in a consultant capacity to provide cost inputs and go through the learning curve with the rest of the team. However, if the cost of a contractor's services exceed 10% of the work being designed, they are disqualified. In addition, even if that limit is not exceeded, the University would risk bid challenges and further expense and delay to the project.

The University initially aspired to bring at least the main contractor a year earlier than they actually did. However, no bids were received in response to the initial request.

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[19] Component 6 of the TVD benchmark received a score of 4.2 on a 5-point scale (in comparison, SMCCV and ABSMC respectively received a score of 4.8 and 3.7).

The integrated team eventually got co-located in an Integrated Center for Design and Construction (ICDC). The ICDC setting started in April 2009, 2 months after the DA subcontractors came on board. The architect and designers relocated to the trailer only after a couple of month. They initially thought of some presence every day spread between the disciplines, but intended to keep most of their designers in their office. Having employees based full time on the site, without quite the same level of comfort as in the office, was something new and “scary” for the designers. This situation didn’t provide quite the interface and level of collaboration required to meet the OSHPD deadlines. As with the Sutter projects, they ended up not being fully co-located, but their presence allowed the ICDC to achieve a tremendous amount of work in a relatively short amount of time. Having everybody in the same place certainly resulted in a lot more fluid collaboration. The Big Room layout was redesigned several times over the course of the project and eventually extended significantly before the start of construction. It was initially designed with no separation between workstations to foster this open and collaborative environment.

6.2.1.3 Integrated governance

There are two levels of integrated governance on this project: captains and senior leadership.

6.2.1.4 Joint responsibility, transparency

As on any job, there were initially *“conflicts, personality battles and things that had to be resolved” (a contractor)*. But once trust had been built, everyone behaved like they were part of the team and participated in generating ideas, executing them, valuing them and pushing them through the project. Thanks to the open environment of the Big Room, people were aware of what was happening, problems surfaced quickly and everyone worked together to solve those problems.

6.2.1.5 Functional interface & modeling process

IPD promotion and awareness occurred from the beginning of the project. Once DPR came on board, the conditions existed for full initiation of IPD/TVD and more formal training began. Key people from each company went to CIFE (Center for Integrated Facility Engineering) at Stanford and had a 4-day workshop to learn why to work together and how to work together. They set up the rules for how the interaction would happen and had discussions about work processes alignment. These meetings were high-level, but they helped the team focusing on priorities at least.

The CIFE workshop helped designing the “modeling process”, which is represented in figure 22. The team was modeling one floor at a time, starting with the top floor. As shown on the process map, the modeling process for MEP followed these 3 main steps:

1. Design: Arup prepares the 2D design documents by setting the main runs, airflows and so forth, with input from the DA subcontractors.
2. Collaborate: DA subcontractors do the 3D modeling, coordination and clash detection. The engineers monitor progress and clarify potential design issues. Modeling and coordinating a 75,000 sf floor was done on a 4-week cycle.
3. Document: Arup flattens the 3D model and adds tags, labels, functional specification documents (FSD) and legends as necessary to submit to OSHPD.

And all along the way, ANSHEN+ALLEN, Arup and the corresponding DA subcontractors did some quality control (QC).

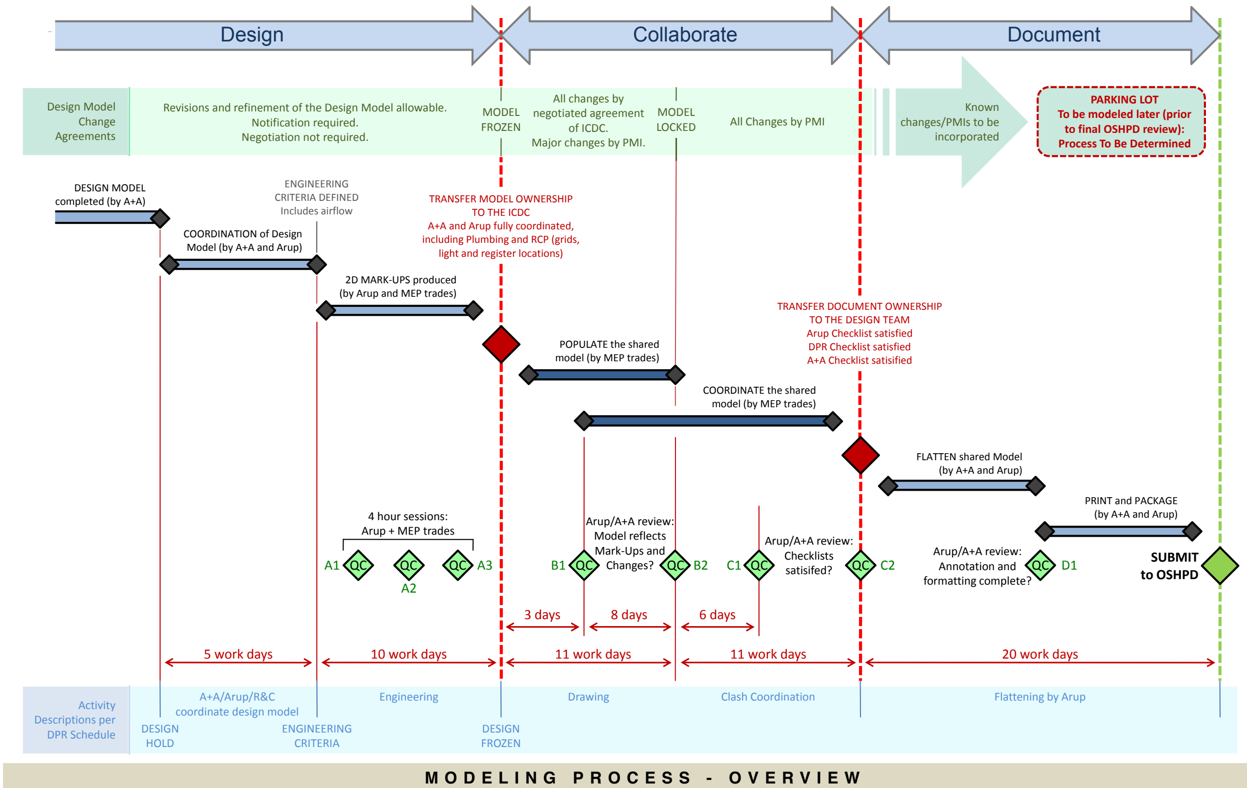

Figure 22: Modeling process overview on UCSF

As is not unusual, roles and responsibilities had to be worked out. The need for this was likely increased by the greater team integration between designers and builders. The extraction of drawings from the model was a primary case in point. It was not a simple matter of pushing a button. Processes, roles and responsibilities had to be clearly specified. An extended team workshop at Stanford's CIFE was devoted to this and related issues.

Regarding design changes, some team members felt that *"there was no alignment in the beginning of what constitutes a move, who has to be notified, what is acceptable to change and what is needed to get going" (a contractor).* Obviously, design iterations are inherent in the design process, and a change during CD would still be cheaper than during construction. But those changes have to be done with some sensitivity as to what their implications are. According to some interviewees, the architects tended to see the displacement of a wall as a minor change, while the downstream impact of that change could actually be quite significant.

On the other hand, architects felt that a lot of the complaints about design changes was coming from the perception that things were more finished than they were really. There was little tolerance on the contracting end for not being done designing. On top of that, there were also late changes happening, coming from different directions and initially not very well channeled. Even if it got better along the way with the PMI process, it appears to have generated some frustration.

The designers tend to work on a progressive specification model, from coarse to fine details, a consequence of which is that nothing is complete until everything is complete. This approach couldn't work on this job, as OSHPD packages were defined floor-by-floor and area-by-area. Going through the building in such a linear fashion is not typical for designers, and aligning work processes was a challenge for everyone. This particular issue, by no means peculiar to UCSF, may have been exacerbated by the timing of the contractors' involvement. If the contractors had been involved earlier, they could have helped the engineers define the systems at a conceptual level, thus gaining understanding about the evolution of the design. Because they got on board at a relatively late stage of the design, they immediately wanted to detail chunks and blocks, while the design was still relatively loose.

According to everyone, a lot of those issues had to do with a lack of understanding of each other's processes and constraints. Working in such a fashion was new to some companies or individuals, and there is a need for more training and education to provide some guidance. Again, if the contractors had come on board earlier, there would have been more time to develop this common understanding. The CIFE training and the development of process maps helped and the level of understanding eventually improved, but the initial misconceptions led to a lot of frustration.

Once the understanding had been developed, the team could look at ways to align work processes. For instance, ANSHEN+ALLEN realized that the way they typically go through a design process from start to finish doesn't fit into this kind of delivery. Within their office, different groups usually carry the design document to a point of time: planning, spacing, walls, interiors, etc. And the interior designer generally doesn't ever look at the document until way down the road, after a few months. On this job, if the interior designer decided to make a change and pushed it back along the line, it had a trickle down effect, because the coordination of the deck hangers might not be valid anymore. The OSHPD submittal process tends to make systems much more intertwined, thus amplifying the implications of any design change. The architect eventually shifted their way of working by having people on site who could react quickly and work together. On a smaller scale, the work structuring process was also facilitated by the Last Planner System®, which helped creating predictable and reliable workflow.

6.2.2 Defining (ends and constraints)

6.2.2.1 Business case

The business case was developed prior to the designers' involvement, well before DPR came on board. Subsequently, scope and budget were reassessed several times, with the help of TBD Consultants, Cambridge, ANSHEN+ALLEN and Arup, because the expected cost was exceeding available funds.

6.2.2.2 Stakeholder values

The designers had frequent meetings with the users to understand their needs and values. The architect's stakeholders were more on the clinical side, while Arup was dealing with the facilities group (the operators that run and maintain the MEP systems). They did mockups and got substantial input from the facility users earlier on. Contractors were often involved in the discussions with the University or the user groups, but the requests generally went through the designers.

Some interviewees felt that the University wasn't always very transparent about what they wanted. *"It was kind of like unpeeling and onion" (a contractor)*. According to a designer, the owner was not initially set up to make decisions well or quickly enough. However, when target costs were reset, every part of the budget took a hit and line item budgets were shared and discussed with the team.

As on any project of this size and given the fast renewal of medical technologies, there had been some late changes in the design based on UCSF standards. Originally, those changes were coming from a number of different directions, but they eventually got well channeled through the PMI process (cf. section 6.2.3.4).

6.2.2.3 Validation phase

Unlike full IPD, the project scope and corresponding budget were "validated" prior to contractors' involvement.

6.2.2.4 Target Setting

From the beginning, the University had expressed interest in TVD. They generally used the terms "Budget" and "Current Estimate" to respectively refer to "Target Cost" and "Expected Cost".

Before the contractors got on board, the University developed targets for the major systems with estimating input from Cambridge, TBD Consultants and three contractors experienced in healthcare construction. The overall budget was broken down by component, and the current estimate for each component was measured against its target.

When DPR came on board, they did with Cambridge a first estimate at 95%DD, which was significantly higher than the previous number. In March 2009, DPR did another estimate with subcontractor input at 100%DD. From this number (the expected cost), UCSF determined a Target Cost 100 million dollars below, which was broken down by clusters. At the beginning of 2010, when the team reached that target, the TVD process transitioned to a stipulated GMP.

In two instances, the University gave a new number to the construction team that they had to reach to get a contract. UCSF was responding to pressure from their Board to take advantage of market opportunity. The economic downturn contributed to the pressure, not least in a reduction in philanthropic giving below what had been expected. Some interviews with project participants suggest that he changing of target costs might have been handled better as regards managing expectations and perceptions. According to one contractor interviewed, until the end of 2010, the VE effort was minor compared to *the "arm wrestle push to just lower costs by virtue of changing the structure of the fees and markup"*. UCSF representatives, on the other hand, expressed disappointment when they perceived a failure to embrace the facts of the situation, and to concentrate efforts on cost reducing innovations.

According to some interviewees, the way the Target Cost was set was never transparent to the team. *"There was never really any particular pathway other than 'it needs to be cheaper', which was discouraging" (a contractor).* This perception was perhaps promoted by the University's bidding the construction work, which was perceived as a way to increase pressure to squeeze cost out. From the University's side, public sector procurement regulations required their action.

The Target Cost got reset in two instances below the initial Target. With hindsight, always perfect, it appears that expectations and perceptions could have been better managed, perhaps through more explicit comparison of previous estimates of available funds and previous estimates of expected costs, both in relation to changes in those estimates. In any case, some members of the project team felt that nothing stops the owner from using its leverage to "change the rules of the game once it has started".

After several months of negotiations, the University and the constructing team agreed upon the terms of the GMP, which includes pending PMI's as allowances.

6.2.3 Steering (means)

6.2.3.1 Domain knowledge in cross-functional teams

When the DA subcontractors came on board, the team was divided into clusters, quite similarly to the Sutter projects:

- Structural
- Exterior Enclosure
- Interiors
- Special Systems
- Mechanical & Plumbing
- Electrical & LV
- Site

Then, the budget allocation was simply an assignment of costs that were currently understood. And the borders between clusters were pretty well defined, even though some changes could impact multiple clusters at a time. Within each cluster, the team looked at some specific ideas or expectations, and determined individual targets based on that. They did some benchmarking and based on the understanding of the design they had at the time and the flexibility offered for the design of each system, they came up with targets per discipline. Therefore, the cost reduction targets were not identical across cluster. And obviously, nobody stopped once a cluster reached its target, since the overall budget value was ultimately the objective.

Clusters were also the structure for intimate collaboration between designers and contractors of a same discipline. Even though it took some time at the beginning for everyone to get comfortable with one another, the collaboration was eventually very positive and the cluster setting became more efficient.

6.2.3.2 Design planning

The team decided to adopt Phased Plan Review (PPR) for OSHPD submittals in order to save time and meet the SB 1953/SB 1661 deadlines. The increments and submittal dates were determined through negotiation between OSHPD, UCSF and ANSHEN+ALLEN. For MEP, there were sub-increments by floor. It allowed the team to incorporate OSHPD feedback on the first submitted floor in the design of the next ones. The main increments were:

0. Geotechnical Report
1. Core and Shell
2. Tenant Improvement
3. Site Fire Water

4. Imaging Equipment
5. Mass Excavation & Building Pad Preparation

While the designers hadn't finished incorporating program changes into the design, the contractors really struggled with the little time offered to meet the OSHPD deadlines. As mentioned in section 6.2.1.5, there were some tensions as contractors needed to lock the design to hit the OSHPD dates. It would probably have helped too if contractors had had input on the OSHPD schedule. Also, even though OSHPD looked at the first increments (first floors) at a conceptual level, they really waited until the entire package went in before looking at it very seriously. It undermined the advantages of this sub-incremental process (by floor), since the team couldn't fully incorporate OSHPD comments for the next floors. The way the increments were set up could maybe be revisited to tackle those issues.

The team did pull scheduling to a small extent when they were looking at the feasibility of hitting some OSHPD commitments. But since most of the deadlines were set and that there was little time left, they just "went for it" and adjusted their manpower resource to get it done on time. The team started using the Last Planner System® before DPR even came on board, with a program from CMiC that Cambridge introduced. It helped creating a transparent environment, which allowed planning the work, tracking activities and identifying reasons for non-completion. PPC was tracked and maintained in the 80% range during preconstruction. As construction started, PPC is around 70% and the team has financial incentives to get it to 80%. The Last Planner System® helped tremendously on this job to remove constraints. If someone foresaw something coming up that could be a problem, it could be brought up and would initiate a collaborative discussion to resolve the conflict. It really helped maintaining the flow.

6.2.3.3 Cost modeling

Once DPR got involved, UC, A+A, Cambridge and DPR jointly explored doing continuous cost estimating, but abandoned the idea, because it would have required a lot of extra work to make the model ready. Consequently, the team decided to do comprehensive estimates approximately twice a year at major design milestones: 95%DD, 100%DD, 20%CD, 50%CD and 95%CD. The rest of the time, they updated the budget on a 2-week basis through the PMI process and tracked quantities as indicators of where the budget was trending.

6.2.3.3.1 3D modeling

The main preconstruction outcome for the DA subcontractors was the production of a coordinated model. The model contains all the information and was the support for coordination. The shop drawings submitted to OSHPD were 2D representations extracted from the coordinated model.

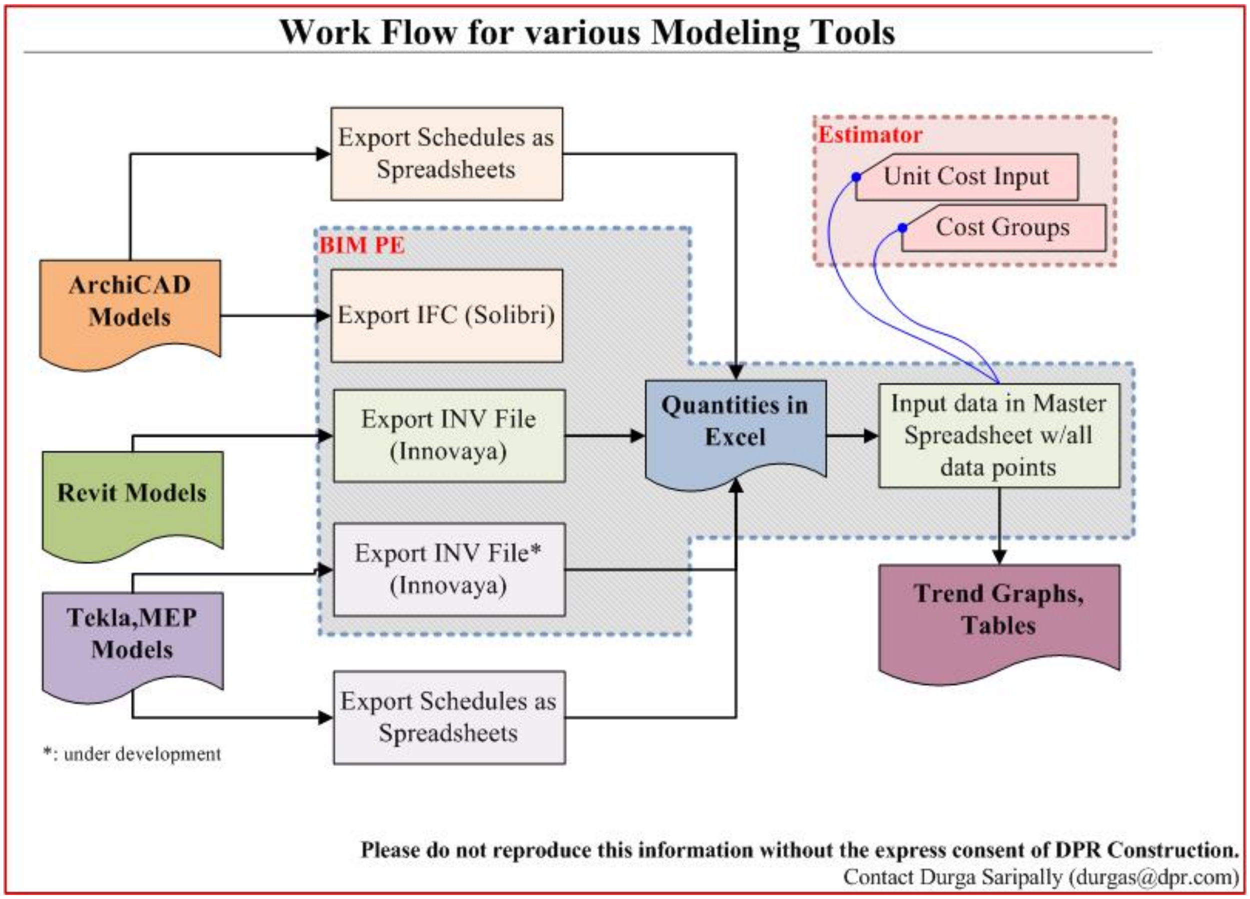

Figure 23: Work Flow for various modeling tools

The architects were drawing in ArchiCAD, an architectural BIM CAD software, which provides more flexibility than Revit. DPR modeled the structural and architectural elements in Revit, based on drawings from ANSHEN+ALLEN. The exteriors were modeled in Tekla, and the MEP trade partners have their own CAD-based models: CAD MEP, CAD-Duct, HydroCAD…

6.2.3.3.2 Quantity trending

The team tracked quantities as an indicator of where the numbers were trending as each floor was modeled. The estimators of the different clusters developed a list of 20 items to trend per cluster, based on cost considerations. Then, at the cluster level, the team looked at the models to see if it was feasible to extract those quantities or not. The choices were based on:

- Are we modeling it?
- Can we reliably pull it out of the model?

The team went through this, eliminated some indicators and agreed on approximately 10 indicators per cluster. Here are some key indicators that were selected:

- Interiors: linear feet of wall, doors, windows, corner guards, guardrails…
- Mechanical: number of grilles and diffusers, pounds of sheet metal…
- Plumbing: pounds of pipes by type (PV, copper…), length of pipes…
- Electrical: linear feet of conduits, panelboards…

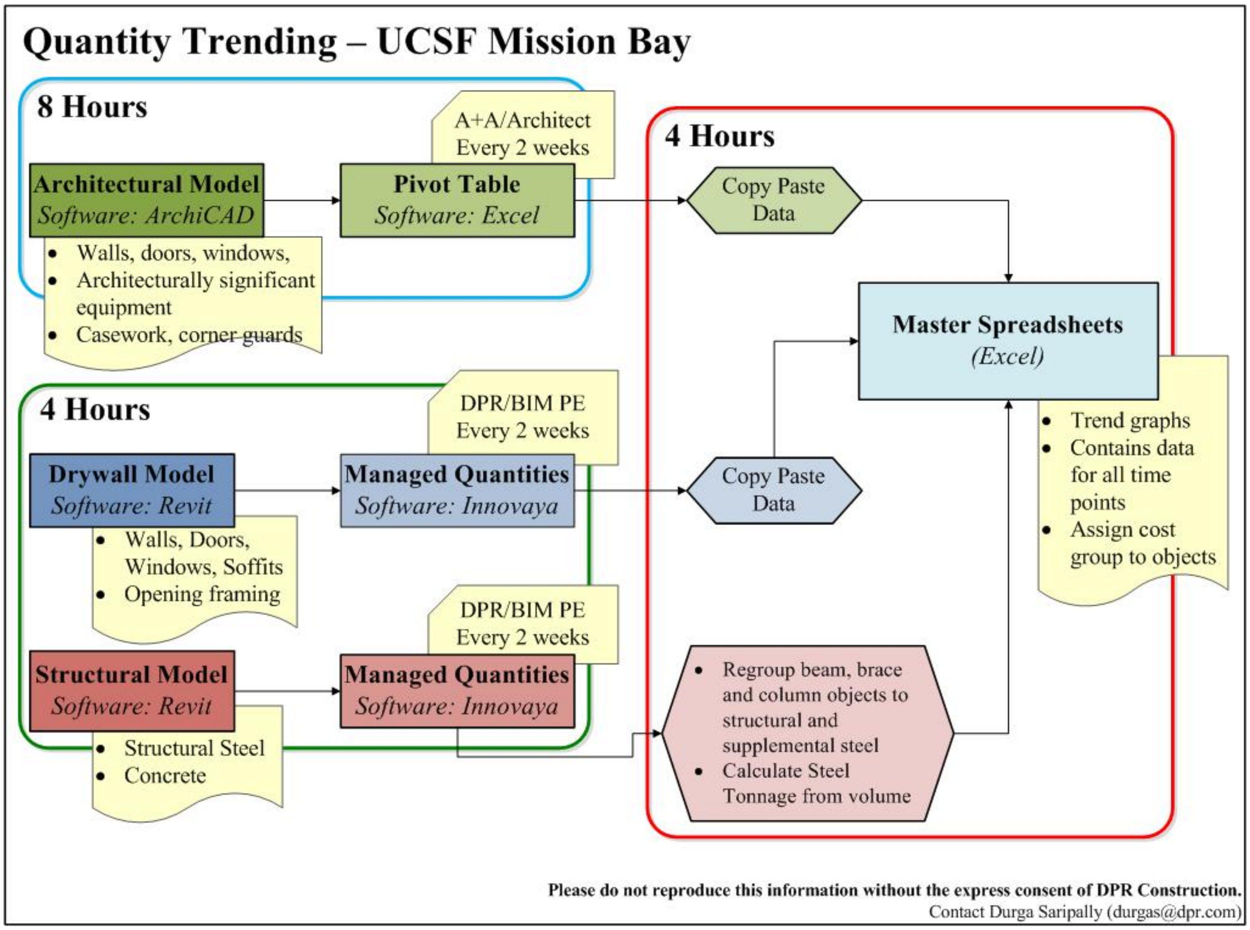

Figure 24: Quantity Trending Process on UCSF

The evolution of the quantities was reported every 2 weeks. For the walls, doors and windows, DPR had 2 sources of data:

1. From the ArchiCAD model. The architects would export quantities into pivot tables.
2. From the Revit model. DPR would automatically extract quantities from the model using Innovaya.

The quantities taken from the 2 models initially didn't match, which led to a lot of quality control (QC) and alignment on DPR's end.

For the finishes, DPR did quantity trending for corner guards and guardrails, because those are discrete objects, easier to count. The rest was taken off manually with OnScreen Takeoff. For the MEP, the process was slightly different. ARUP provided 2D single line drawings. The MEP subcontractors were taking those drawings and modeling one floor at a time, starting from the top floor. So when they started trending, they had only one floor at a time. To compensate for what wasn't modeled yet, the subcontractors added lump sums and factors based on what they had on the budget.

According to all interviewees, Quantity trending was more about making predictions and doing quality control on the model than really influencing design decisions. If implemented earlier on, it could have helped making more substantial design decisions. And quantity trending only gave limited input into the PMI process, since PMI's deal with things that are not in the model yet.

6.2.3.3.3 Cost estimating

The contractors did not implement continuous cost estimating as on the Sutter jobs. Out of all DPR's self-performed work, drywall is the only item for which they used quantities from the model. For all the rest, they couldn't really use the model because of tagging issues and were therefore doing manual takeoffs from 2D drawings.

However, the team was able to produce budget updates every 2 weeks through the PMI process, detailed in the next section. Comprehensive traditional estimates were done every 6 months at major design milestones. And between those milestones, the contractors would re-estimate the areas affected by a PMI change to estimate the cost implication of the change and update the current estimate accordingly if the PMI was accepted. Budget reporting was mostly useful for the owner to see where the budget was trending. Although cost estimating set directions for the budget, it clearly did not influence proactively the design on this job.

6.2.3.4 Analysis of alternatives

The PMI process is the counterpart of the Risk & Opportunity log process on the Sutter jobs. As represented in figure 25, it was used to bring up any risk item or VE opportunity. Anyone could initiate a PMI by filling out a PMI form. Affected parties would then assess the impact of the change in terms of:

- Cost (add or deduct);
- Quality (maintainability, sustainability, operability, aesthetics, etc.);
- Schedule.

The completed PMI form would then be submitted to captains' approval. If the change was substantial or of sensitive nature, the approval process would require an additional step: senior leadership approval. Once accepted, the PMI would be incorporated in the model and its dollar implication would be included in the next budget.

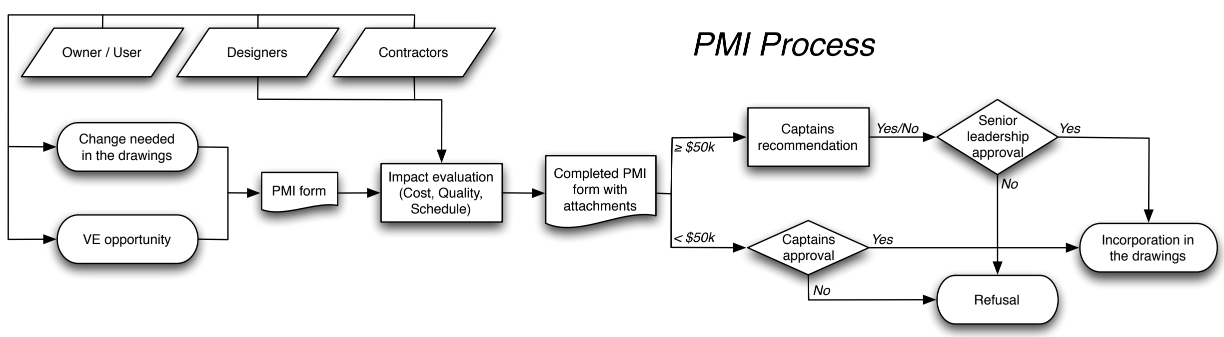

Figure 25: The Project Modification and Innovation (PMI) Process on UCSF

The PMI process was very useful for structuring the VE effort and presenting design alternatives in a standard and informed fashion. It helped channeling the changes in a formal process that anyone could have access to. It gave the owner a quick feedback on the price of things the team was considering doing and whether or not it was viable to go further down the line and get the formal pricing. Even if it had a lot of impact on the design and the budget, the changes that went through the PMI process were a little granular, a little less big picture. This would have been a much more greater process, had it been implemented at DD phase. Through the PMI process, the team is doing Set-based Design on very specific areas for certain VE ideas. There were only very few instances where designers followed this Set-Based approach for large design concepts before the contractors got involved.

6.3 Results

The budget evolution cannot be shared here because of confidentiality issues.

So far, this TVD implementation enabled to reduce significantly the current estimate and come to an agreement for the GMP. Here are some reasons why the price went down:

- **Scope deductions.** The biggest scope reductions were architecturally driven (square footage reduction, consolidation of the outpatient buildings into a single one, etc.). However, all areas previously shelled were restored in the final GMP. On the engineering side, they also cut down some scope, which might have affected the initial desires for redundancy in the systems.
- **The economic situation.** It was definitely a pressure for contractors, which forced them to be more aggressive price-wise and reduce fees.
- **VE ideas.** The team proposed a lot of VE ideas through the PMI process, which helped reducing the current estimate and bringing more value to the customer. As examples, the mechanical contractor changed the supply side of terminal boxes to cheaper ones, which saved approximately a million dollar. The electrical contractor suggested to eliminate the cable tray that was going to be used for all the IT cabling, and use instead custom designed J hooks and flat bars. This change saved hundreds of thousands of dollars.
- **Reduced variability and increased productivity.** The constructing team worked a lot on prefabrication ideas, which gives higher reliability and faster site installation. More generally, the effort to produce a fully coordinated model during preconstruction will make construction much more reliable. Consequently, contractors were able to release the “built-in” contingency from their estimates and increase their productivity rates on-site.

7 Areas for improvement

7.1 Lack of anchorage of the Target Cost

On the 3 case studies, some project team members felt that the owners were not fully transparent about how the Target Cost was set. If there is no clarity from the beginning, the "rules of the game" might change along the way. More generally, the business case was not really shared with the team on any of those 3 projects. And it doesn't seem that an Allowable Cost—what the owner is willing and able to pay to get use of the asset—was determined either. Rather, a more traditional reliance on cost estimates was used as the basis for budgeting. The TVD benchmark for business planning and plan validation is represented in figure 26.

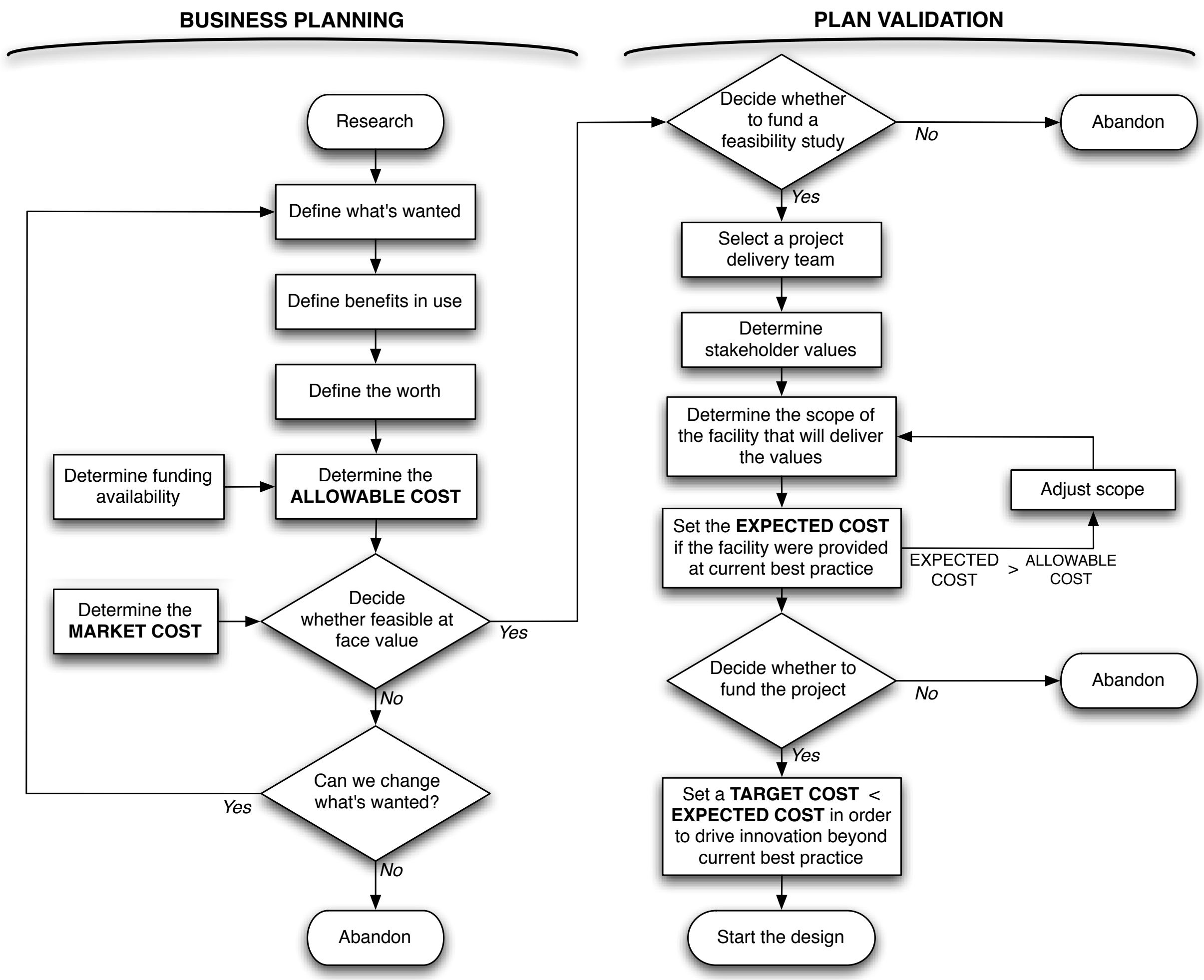

Figure 26: TVD benchmark for the business planning and plan validation phases

When market cost falls below allowable, what the client is willing and able to spend, that can reduce the project budget. A reduction in project budgets can also occur as a result of a reduction in available funding. Both cause discomfort for all members of the project team, as they struggle to avoid reducing their fees through innovations in product and process design. An example of the latter is innovative purchasing, an example of which occurred on UCSF, when Schuff recommended pre-purchasing steel. The The market can also be your friend, again illustrated from UCSF, which saved $50 million on contracts with trade contractors procured via competitive bidding.

7.2 Tensions related to contractual terms

Both on ABSMC and UCSF, there were some tensions before signing the contract, an EMP and GMP, respectively. We can wonder if those negotiations could have happened earlier, right after plan validation. Before the GMP is actually signed, the team might not be as much committed to the process, as they are not "playing with their money" yet. However, by signing it that early, there will be a lot more uncertainty and there is a risk that the contractors cannot yet commit to a Target Cost, without hiding a lot of contingencies in their estimates. More generally, the thresholds for painsharing and gainsharing could be thought over again, as represented on figure 27.

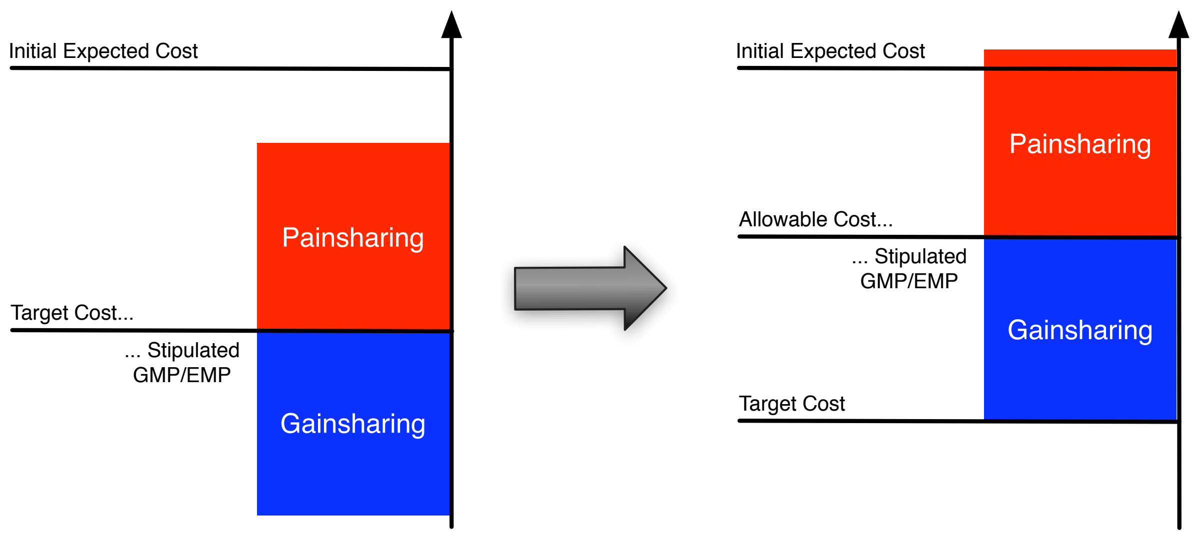

Figure 27: Determination of the Painsharing/Gainsharing areas: current practice (left) and "recommended" practice (right)

[To clarify figure 27 in relation to the UCSF Hospital Project, the "allowable cost" included a $27 million contingency plus allowances in the GMP that were to be exhausted prior to contractors losing fee.]

Also, the way the actual cost is tracked during construction should be clearly determined in advance. If at some point, the team is trending over budget, their monthly fee payments get reduced accordingly. With the current IFOA terms, the team is incentivized to pull money out of the "IPD contingency" bucket to cover their unanticipated costs, while the owner is encouraged to leave this bucket intact to keep the team motivated and to maximize its savings at the end of the job. There might be tensions regarding what constitutes a change that should be covered by the "IPD contingency" or not. Therefore, the mechanisms that dictate the usage of this bucket shall be agreed upon from the beginning.

It should be noted that these first two areas of opportunities fall under the owner's responsibility.

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7.3 Differences in work processes between designers and builders

A better job could be done upfront to educate the team members about each other's processes and develop a common level of understanding. While contractors often reproach designers for changing the design without having the downstream implications in mind, iterations are inherent to the design process. Working in integrated teams requires aligning work processes of designers and contractors. On the 3 projects, it would probably have been beneficial to hold work sessions during which the different partners could present to the team their constraints and work processes. Once common understanding has been developed, work structuring should be a key aspect of the design planning process, through process-mapping exercises for instance. It would be worthwhile further studying how the alignment of work processes took place on those 3 projects.

7.4 Project organization and governance

Even though it was not a real source of criticism, it might be interesting studying the appropriateness of the project organization and governance to support TVD. Was the cluster breakdown optimal? Would it be worth periodically assessing the partners' commitment to TVD? Many interviewees on the Sutter projects reported that the Big Room meetings were not as efficient as they could be. More generally, could team organization interfaces be improved?

7.5 Handling users requests

On ABSMC, many considered the influence of the users as one of the biggest challenges for the proper implementation of TVD. How could the interests of the end users be better aligned with those of the rest of the team? Even if it is not necessarily up to the project team to decide, the end users input should be more "channeled", by giving a limited window of time and establishing a clear process for handling their requests. Too many times, some requests were "imposed" to the team without assessing their downstream implications first, which caused a lot of avoidable design rework.

7.6 Modeling & estimating

At first, team partners should agree from the beginning on modeling and estimating tools and try to use the same platforms if possible. Software incompatibilities seemed to have created some waste on those projects: impossibility of doing model-based estimating, parallel models, etc.

The way conceptual estimates are developed could also be improved. Some methods might be worth examining to determine accurately an expected cost from the client requirements:

- Haahtela's TaKu™ model (Pennanen and Ballard, 2008);
- Boldt's Quarterback Rating System (Boldt, 2008);
- Beck's DProfiler™ software.

Once a good conceptual estimate has been developed, the team shall refine it progressively (by adding more granularity) when there is enough certainty. Later on, there is room for more automation in the estimating process through better usage of model-based estimating and direct linkage of the 3D models and cost database (cf. section 4.2.3.3).

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7.7 How can cost proactively influence the design?

TVD strives to proactively design to targets. The teams on the 3 case studies certainly did collaborative value engineering, and the high level of integration on SMCCV (for instance) enabled almost real-time cost and constructability input from the contractors. However, the team did not proactively design to targets. As mentioned in the previous section, an accurate conceptual estimate should be developed based directly on the clinical program and the client requirements. From this service-line estimate, the team could collaboratively work at designing building components to the identified targets.

We can also wonder if the VE processes ("Risk & Opportunity log" process on the Sutter jobs, and "Project Modification and Innovation" process on UCSF) could be ameliorated. The project team only seldom used a set-based design approach. Could tools be used to help identify VE opportunities (function analysis, reverse engineering, product breakdown engineering, etc.)? Also, once alternatives have been identified, the A3 process could be more systematically followed. Would sound decision making techniques (such as Choosing By Advantages) help for alternatives selection?

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