Technical Report

Part 1 of 5: The Application of Target Value Design in the Design and Construction of the UHS Temecula Valley Hospital

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1 Introduction

1.1 Research Objectives

Target Value Design (TVD) is "a management practice that drives the design [and construction] to deliver customer values within project constraints" (Ballard, 2009). It is an application of Taiichi Ohno's practice of self-imposing necessity as a means for continuous improvement (Ballard, 2009). The TVD Research Group was originally a three-year research initiative launched in June 2010 by UC Berkeley's Project Production Systems Laboratory (P2SL) and DPR Construction Inc. to study the application of TVD on three hospital projects. The original goals of the group were to:

1) Improve TVD application within IPD projects.
2) Adapt TVD to other applications such as Design-Build and proposal development (Denerolle, 2011)

In 2013, the P2SL TVD Research Group expanded in both membership and in the scope of the research efforts. Several companies within the Northern California AEC industry joined the research group. The scope of the research investigation expanded to include the study of Universal Health Services' Temecula Valley Hospital Project (Table 1) and the Palo Alto Medical Foundation's Sunnyvale Medical Office Building (the subject of a separate report). Stephane Denerolle (2013) previously documented the application of TVD in the design phase of the three original case study projects: Sutter Health Eden Castro Valley, Sutter Health Alta Bates Medical Pavilion, and the UCSF Mission Bay Hospital. This technical report documents both the design and construction of the UHS Temecula Valley Project (Table 1). This study compares the practice of TVD on Temecula Valley to P2SL's process benchmarks.

The goal of this technical report is to present an in-depth case analysis of the TVD application on the UHS Temecula Valley Project. This report documents: (1) the project's history, (2) how TVD was applied during design, (3) how TVD was applied in construction, (4) the challenges of TVD, (5) the outcomes of the project, (5) the lessons learned, and (6) key innovations that resulted from TVD. For industry practitioners, this report may help them better understand TVD and be able to transfer some of these practices to their own projects. For researchers, this report can be a source of empirical data for theory building and replication.

1.2 The Case Study Project

The UHS Temecula Valley Hospital (Figure 1) is a $151 million; five-story, 140-bed, 177,508-sq.-ft hospital located just north of San Diego in Southern California. The hospital includes 20 intensive care units (ICU), five high-tech surgical suites, a cardiac catheterization lab/interventional suite, and emergency room services (DPR, 2014). The new hospital project was commissioned and is operated by Universal Health Services (UHS), Inc. In the future, UHS plans to add an additional 150 beds, a medical office building, and a fitness center next to the current project site.

Figure 1: The Temecula Valley Hospital[1]

Table 1: Case study characteristics

	UHS Temecula Valley
Total Project Cost	$151 million
Estimated Maximum Price (EMP)[2]	$125 million
Square Footage	177,506
Number of Patient Beds	140 patient bed
Collaboration level	Multi-party Integrated Project Delivery
Contract Type	Consensus Docs 300

2 Literature Review

2.1 Target Value Design

Target Value Design (TVD) is an adaptation of Target Costing, a strategic profit planning practice used in new product development (Cooper and Slagmulder, 1997). "To ensure that products are sufficiently profitable when launched is to design them to a target cost determined by subtracting the product's desired profit from the expected selling price. Under this approach, cost is viewed as an input in the design stage rather than an outcome of it" (Cooper and Slagmulder, 1997). Target Costing has been used

[1] Retrieved from the project blog at from: http://blog.hmcarchitects.com/Temecula-Valley-Hospital (03/02/2014)

[2] Total Project Cost includes owner costs and costs for work scopes within the risk pool (reimbursable), and for work scopes outside the risk pool (fixed price). EMP only includes costs for work within the risk pool.

in the Japanese industry since the 1960s under the name “Genka Kikaku” but it remained a trade secret until the 1980s (Feil et al., 2004). Target Costing and Kaizen Costing make up the total cost management program of Japanese automotive and manufacturing companies (Monden and Hamada, 1991). Within the Japanese construction industry, Target Costing is regarded as one of the most important management practices (Yook et al., 2005).

Target Costing was documented in the construction industry in the early 1990s by British Petroleum (BP) in the development of the Andrew Oil Field (Sakal, 2005; Knott, 1996). The relational contract and terms used for Target Costing by BP would later become known as Project Alliancing (Sakal, 2005), which is practiced in Europe and Australia. Nicolini et al. (2000) reported two case studies of Target Costing in the UK construction industry. Unfortunately, the application was unsuccessful because, according to the case study authors, the builders had become accustomed to buying and selling rather than designing and making.

Ballard and Reiser (2004) reported the first application of Target Costing in the United States construction industry on the St. Olaf Fieldhouse Project, which was completed in 2002 (Ballard and Reiser, 2004). The term “Target Value Design” was later coined by John Barberio to emphasize that the practice is not purely motivated by cost reduction but rather to ensure that the appropriate value is delivered to the customer (Macomber et al., 2007)—a feature of product development’s target costing, but not evident in the name itself. During the 5-year research project with the P2SL TVD Research Group, the term “Target Value Delivery” has emerged to emphasize that TVD is applicable beyond the design phase. The goal of TVD is to deliver value to stakeholders within the physical, social, and financial constraints of the project.

Since its introduction, TVD has been widely accepted by the construction industry in the United States and appears in legal documents such as Sutter Health’s Integrated Form of Agreement (IFOA) and the ConsensusDocs 300 (Lichtig, 2005; ConsensusDocs 2014). Several researchers have reported positive cost to market performance and cost certainty performance of TVD (Zimina et al., 2012; Do et al., 2014).

2.2 Target Value Design Benchmarks

The University of California, Berkeley’s Project Production Systems Laboratory (P2SL) periodically publishes a TVD Process Benchmark. The first version of the TVD Process Benchmark was published in 2005, then revised and republished in 2009. (Ballard, 2011). The current TVD Benchmark provides the guidelines for applying TVD and includes:

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 projects’ allowable and market cost.

2. The business case is based on a forecast of facility life cycle costs and benefits[3], 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.

[3] This is the original language of the Benchmark, but on reflection, a better term is ‘whole life costs and benefits’. “Life cycle” is commonly used to refer to the costs associated with operations and maintenance, whereas “whole life” includes the business use of the constructed asset. Example: Operations and maintenance of a hospital building versus the delivery of healthcare in the building.

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

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 collaboration between members of the project team—'over the shoulder estimating'.

12. The Last Planner® system is used to coordinate the actions of team members.

13. Targets are set as stretch goals to spur innovation.

14. Target scope and cost are allocated to cross-functional TVD teams, typically by facility system; e.g., structural, mechanical, electrical, exterior, interiors, etc.

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 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.

The TVD Process Benchmarks were derived from theory and from empirical studies of TVD projects. Researchers from the UC Berkeley's Project Production Systems Laboratory (P2SL) have been conducting action research on TVD since 2002 and the benchmarks reflect practices that have been observed to lead to favorable outcomes on TVD projects. This research compares the application of TVD on the UHS Temecula Valley Project to the TVD Process Benchmarks published by Ballard (2011). Based upon our findings from this case study (and from the 5-year research on TVD), the UC Berkeley's P2SL will publish an updated process benchmark to incorporate lessons learned and the "best practices" in TVD, as well as challenges and opportunities for further improving the benchmark.

2.3 Integrated Project Delivery (IPD)

"All projects contain three domains within which they operate: the project organization, the project operating system, and the commercial terms binding the project participants" (Thomsen et al., 2009; Figure 2). The project organization refers to how the project members are organized and includes the organizational structure, communication flows, decision-making process, project governance, etc. On a construction project, people can come at various stages and stay for varying amounts of time depending upon their role and their scope of work. Integrated Project Delivery (IPD), a project organization practice, has been gaining popularity within the United States since the creation of the firm named Integrated Project Delivery in 1999, led by Owen Matthews of Westbrook Air Conditioning in Orlando, Florida (Matthews and Howell, 2005; AIA, 2007; Cohen, 2012). In addition to multi-party contracts, IPD is characterized by early involvement of the key participants including the contractors, designers, trade partners, and facilities managers, and by promoting collaboration through co-location, big room meetings, and shared governance. Raisbeck et al. (2010) stated that the notable differences between IPD and Project Alliancing (a project organization practiced in Australia and Europe) is that the use of Building Information Modeling (BIM), co-location, and big room meeting are mandatory on IPD projects. With Project Alliancing, these practices are not always required (Raisbeck et al., 2010).

Figure 2: The LCI triangle model (Thomsen et al., 2009)

The operating system includes methods and tools used to manage the project. The Lean operating system, which can be used with IPD, includes the Last Planner System®[4], A3 problem-solving/reports, Set-Based Design, Choosing by Advantages, Target Value Design, etc. In the case study, the project relied heavily on the Lean operating system as the contract language required the use of Lean management methods.

The commercial terms are the contract language that binds the participants together. IPD projects typically use a multi-party relational contract such as the Integrated Form of Agreement (IFOA) or the ConsensusDocs 300 (Lichtig 2005; Thomsen et al. 2009; Ballard and Howell 2005)[5]. In situations where signing a multi-party contract is prohibited, as is the case for some public entities, more traditional GMP and Lump Sum contracts can be modified to promote the behaviors of IPD and encourage the use of TVD (Darrington and Lichtig, 2010). The University of California San Francisco's recent hospital project was such an 'IPD-ish' project[6]. It is included in Denerolle's (2009) report on the design phase. Its construction phase and outcomes will be the subject of a future report from this research.

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[4] The Last Planner System is a registered trademark of the Lean Construction Institute (leanconstruction.org).

[5] AIA (American Institute of Architects) forms of contract are also used on IPD projects, but do not specify lean management as the operating system.

[6] We follow the common distinction in use of the terms "IPD" and "IPDish", but it may be more useful to think in terms of shared risk and reward, with different contractual means for achieving alignment of commercial interests.

2.3.1 Sutter Health's 5 Big Ideas

In 2004, Sutter held a conference with its service providers outlining their vision for the future (Macomber, 2004). At the time, Sutter was faced with a $6 billion construction program. In the past years, many of their projects had been over budget, over schedule, did not deliver its intended value, and in some instances resulted in lengthy litigation. Their goal at the conference was to: "set out to transform how capital projects are designed and delivered. This initiative is noble and necessary. They believe that capital projects cost too much; they take far too much time; they often fall short of their objectives; and they kill or injure too many along the way. It need not be this way" (Macomber, 2004). With the help of Lean Project Consulting, Inc. Sutter developed their 5 Big Ideas as the foundation of their Lean Project Delivery System. These 5 Big ideas form the basis of the Integrated Form of Agreement, the first multi-party contract for Integrated Project Delivery (IPD), as well as other relational contracts such as the Consensus Docs 300 (Lichtig, 2005).

Sutter's 5 big ideas are used in this report to gauge the cultural outcomes of the project. The soft metrics of the cultural outcomes include: degree of collaboration, relatedness amongst the project team, learning, optimizing for the whole, and managing the project as a network of commitments (Figure 3). A survey was sent out to the project team and the outcome is included in the results section.

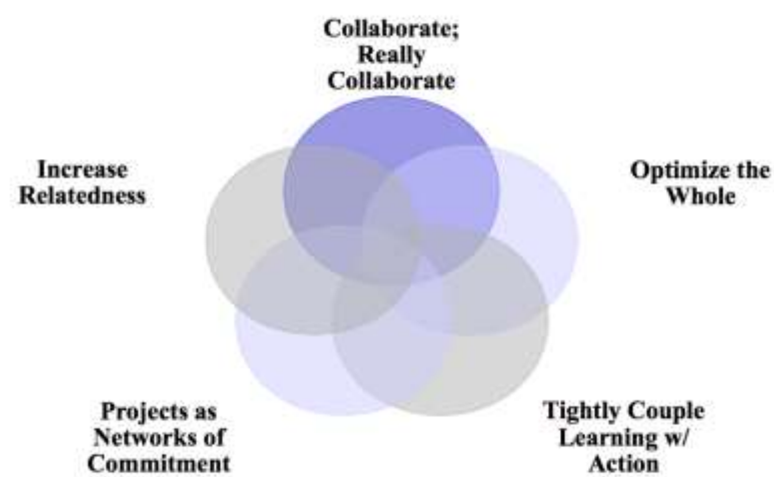

Figure 3: Sutter's 5 Big Ideas (Macomber, 2004)

Collaborate, Really Collaborate

> " Constructable, maintainable, and affordable design requires the participation of the range of project performers and constituencies. Since abandoning the master-builder concept, and separating design from construction, we have been patching together a poorly conceived design practice. Value engineering, design assist, and constructability reviews mask an underlying assumption – that design can be successful when separated from engineering and construction. Design is an iterative conversation; the choice of ends affects means and available means affects ends. Collaborative design and planning maximizes positive iterations and reduces negative iterations." (Macomber, 2004)

Optimize the Whole

> "Project work is messy. Projects get messier and spin out of control when contracts and project practices push every activity manager to press for speed and lowest cost. Pushing for high

productivity at the task level may maximize local performance but it reduces the predictable release of work downstream, increases project durations, complicates coordination, and reduces trust. In design, we incur rework and delays. In the field, this means greater danger. We have a significant opportunity and responsibility to reduce workers' exposure to hazards on construction projects. Doing so can bring about greater than 50% improvements in the safety on the work site. We are committed to do all that is possible so that the people who build these projects are able to go home each night the way they came to work. The way we understand work and manage planning can increase that messiness or reduce it." (Macomber, 2004)

Tightly Coupled Learning with Action

"Continuous improvement of costs, schedule, and overall project value is possible when project performers learn in action. Work can be performed so that the performer gets immediate feedback on how well it matched the intended conditions of satisfaction. Doing work as single-piece flow avoids producing batches that in some way don't meet customer expectations that later on must be reworked. The current separation of planning, execution, and control contributes to poor project performance and to declining expectations of what is possible." (Macomber, 2004)

Projects are Single Purpose Network of Commitments

"Projects are not processes. They are not value streams. The work of management in project environments is the ongoing articulation and activation of unique networks of commitment. The work of leaders is bringing coherence to the network of commitments in the face of the uncertain future and co-creating the future with project participants. This contrasts with the commonsense understanding that planning is predicting, managing is controlling, and leadership is setting direction." (Lichtig, 2005)

Increase Relatedness

"People come together on AEC projects as strangers. They too often leave as enemies. Facilities projects today are complex and long-lived, requiring ongoing learning, innovation, and collaboration to be successful. The chief impediment to transforming the design and delivery of capital projects is an insufficient relatedness of project participants. Participants need to develop relationships founded on trust if they are to share their mistakes as learning opportunities for their project, and all the other projects. This will not just happen. However, we are learning that relationships can be developed intentionally." (Lichtig, 2005)

3 Research methodology

3.1 Case Study Method

According to Yin (2009), the case study method is appropriate when: 1) asking "why" and "how" questions, 2) if the researcher has little control in the experiment, 3) if the focus is on a contemporary phenomenon within real-life context. Eisenhardt (1989) defines a case study as "a research strategy that focuses on understanding the dynamics of a single setting". A properly designed case study can be generalized and used to develop theories (Eisenhardt, 1989; Flyvbjerg, 2006). In order for a case study to be scientifically rigorous, its design and data collection practices must meet: 1) construct validity, 2) internal validity, 3) external validity, and 4) reliability (Yin, 2009).

Construct validity refers to the degree to which the research is measuring what it was designed to measure. Internal validity deals with the degree to which the causal relationships drawn by the research is warrant based on the data collected. External validity refers to the scope and boundary within which the findings from the case study can be generalized. And finally, the reliability of the research ensures that proper research protocols were taken so that other researcher can reproduce the results if they followed the same research steps (Yin, 2009).

In order to maintain construct validity, Yin (2009) recommends the following tactics: 1) use multiple sources of evidence, 2) establish a chain of evidence, 3) have key informants review the draft of the report. To maintain internal validity, Yin (2009) recommends using logical models and pattern matching techniques. To maintain external validity, Yin (2009) recommends using replication logic to compare the findings from multiple cases. And finally, to maintain reliability, the researcher should use a case study protocol and develop a case study database (Yin 2009). The research for this technical report follows Yin's (2006) recommendations in order to maintain construct validity, internal validity, external validity, and reliability. After writing the technical report, we asked project participants to review our draft to ensure accuracy.

3.2 Analytical framework

This study uses a modification of Denerolle's analytical framework (Denerolles, 2013; Table 2). The research framework for this study includes four major sections: (1) project definition, (2) steering to target during design, and (3) steering to targets during construction. Table 2 lists the key concepts and the portion of the existing TVD benchmark that references each component.

Table 2: Analytical Framework Matrix

		Key concepts	TVD benchmark practices
Project Definition	**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 projects' allowable and market cost. The business case is based on a forecast of facility life cycle costs and benefits
	Stakeholder Values	Definition of value Link value directly to design components Scope changes	All team members understand the business case and stakeholder values
	Conditions of Satisfaction	Translating Stakeholder values into measurable outcomes	
	Forming the Team	Early involvement	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.
	Lean Training	Training the project team on the basics of Lean philosophy, methods, and tools Promote and develop a Lean culture	
	Target Setting	How are the targets set? Linkage to business case	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. Targets are set as stretch goals to spur innovation.

	Validating Targets	Ensuring that the targets are achievable	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. The feasibility study produces a detailed budget and schedule aligned with scope and quality requirements.
	Contractual Structure / Sharing Risk and Reward	Contractual agreement Incentives, accountability	Some form of relational contract is used to align the interests of project team members with project objectives.
Steering to Targets During Design	**Cross Functional Team For Design**	Clusters Collaboration	The customer is an active and permanent member of the project delivery team. Target scope and cost are allocated to cross-functional TVD teams, typically by facility system; e.g., structural, mechanical, electrical, exterior, interiors, etc.
	Integrated Governance	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.	The project is managed by the people in the risk pool
	Joint Responsibility and Transparency	Process for making decisions within a shared governance model which ensures that value is being delivered	IPD members share in the roles and responsibility of managing the project
	Co-location / Big Room Meetings	Allow for close collaboration and exchange of ideas	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.
	Collaborative Design Conversation	Talking before drawing	
	Simulation of Operations	Simulate the operations of the space to inform its design	
	Last Planner for Design	Coordinate and organize key milestones and decision in the design phase	The Last Planner® system is used to coordinate the actions of team members.
	Set Based Design	Eliminate negative iteration by keeping a set of feasible alternatives	
	A3s	Document improvements and decisions on a single page	
	Value Engineering	Reducing cost through innovation while maintain the desired functionalities, capacities, and quality	
	Cost Modeling and Cost Tracking	Cost estimating	Cost estimating and budgeting is done continuously through collaboration between members of the project team—'over the

		Budget reporting	shoulder estimating'. TVD teams update their cost estimates and basis of estimate (scope) frequently.
	Building Information Modeling	BIM	
	Risk Identification and Risk Management	Identify, classify, and mitigate risks	
	Moving Money Between Boundaries	Transfer of money and scope across organizational boundaries	
Steering to Targets During Construction	**Last Planner for Construction**	Coordinate the key activities and milestones during construction	The Last Planner® system is used to coordinate the actions of team members.
	Location Based Planning	Integrate space and time as a resource to avoid trade stacking	
	Value Stream Mapping	Understand the value of a process so that waste can be eliminated	
	Process Mapping	Mapping out and standardizing common processes	
	First Run Studies	Prototype a production run to learn and improve Record trades at work to find areas for improvement	
	5 Whys Analysis	Learning from breakdowns	
	Community of Practice	Develop a group that shares best practices and continues the Lean journey	
	Shared KPIs	Communicating and sharing project and production data with the integrated team	

3.3 Data Collection Techniques

3.3.1 Interviews

Interviews are the main source of data for this research. To collect data from several different perspectives, the researcher conducted face-to-face and telephone interviews with the key participants from the UHS Temecula project. These interviews were semi-structured and typically lasted between 30 minutes to 1 hour (although some lasted much longer). The notes from the interviews were compared with other sources of data in order to triangulate the findings. Table 3 shows the list of interviewees, their title, and the date of the first interview. As an iterative process, the researcher maintained contact with several of the interviewees throughout the research in order to request for information, to ask for the context of the data, and to gather in-depth examples for this report.

Table 3: Interviewees on the case studies

UHS Temecula Valley

Name	Title	Date
Scott Dater	Electrical Trade Partner	11/13/2013
Jason Herrera	General Contractor (Drywall)	06/15/2015
Kristen Hill	Lean Coach	07/20/2015
Tara Laski	Owner's Rep	10/29/2013
Ken Lindsey	Mechanical Trade Partner	12/17/2013
Tom Mccready	General Contractor	11/05/2013
Brent Nikolin	General Contractor	11/05/2013
Bill Seed	Owner	10/17/2013
Lee Tsangeo	General Contractor	10/25/203
George Vangelatos	Architect	10/28/2013
Steve Wilson	Architect	11/4/2013
George Zettel	General Contractor	10/29/2013

3.3.2 Document Analysis

In addition to interviews, several other data sources were used to expand the findings. By relying on several independent sources of evidence, the researchers were able to increase the construct reliability of the research. The additional data sources include:

1) Schedule and Budget Reports
2) Contract Documents
3) A3 reports
4) Lessons Learned Presentation
5) Other forms of documented information on the project (e.g., Excel files, photos, and videos)

The UHS Temecula Valley project was completed in August of 2013. One limitation of this research is that we measured TVD application after the project had been completed. People moved to different projects and their personal accounts may be distorted over time. In order to counteract this effect, the research carefully triangulated evidence from multiple sources and used documented data to support the interviews. One benefit of collecting data after the project has already been completed is that we can report on both the application and the outcomes. The lessons learned presentations that were collected by the participants at the end of these projects have been one such valuable resource of information.

3.3.3 Surveys

Two surveys were sent to the participant of the project. The first survey was sent to 9 participants of UHS Temecula on March 18, 2014. The survey asked the participants about the components of the TVD benchmarks and the Lean Construction methods (i.e., CBA, Set-Based Design, and A3 reports) that were used on their project. The second survey was sent out in September 2015. The second survey focused on the cultural outcomes of the project. The scale of the survey ranged from 1 to 5 (1 => highly disagree, 2 => disagree, 3 => neutral, 4 => agree, 5 => highly agree). This section discusses the outcomes of the first survey. The outcomes of the second survey are available in the results section.

The goal of the first survey was to gauge quantitatively the TVD application of the projects and to serve as starting point for more in-depth interviews. There were 6 respondents from the Temecula Valley Project. Although the number of sample points is too small to be statistically significant, the results from the survey gave a high-level picture about the TVD application. The results table included: (1) the component of the TVD benchmarks, (2) the mean score, (3) the lower range, (4) the upper range, and (5) the standard deviation. Standard deviations greater than 1 (highlighted in Table 4) indicate areas where there were differing opinions between the participants. Standard deviations less than 1 indicate that there was more or less a consensus.

Table 4: Results from a Survey Conducted to Rate the Implementation of the TVD Benchmark

Components of the current TVD benchmark (rated on a scale of 1 to 5)	**Temecula**			
	Mean	Lowest Rating	Highest Rating	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.	3.8	3	4	.5
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.	3.8	**1**	**5**	**1.6**
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.	3.8	**1**	**5**	**1.6**
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.	4.4	3	5	.9
5. The feasibility study produces a detailed budget and schedule aligned with scope and quality requirements.	3.8	**2**	**5**	**1.3**
6. The customer is an active and permanent member of the project delivery team.	4.4	**2**	**5**	**1.3**
7. All team members understand the business case and stakeholder values.	4.4	3	5	.9
8. Some form of relational contract is used to align the interests of project team members with project objectives.	4.8	4	5	.5
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.	3	**1**	**5**	**1.6**
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.	4.4	3	5	.9
11. Cost estimating and budgeting is done continuously through intimate collaboration between members of the project team—'over the shoulder estimating'.	4.2	3	5	.8
12. The Last Planner® system is used to coordinate the actions of team members.	4.4	3	5	.9
13. Targets are set as stretch goals to spur innovation.	4.2	3	5	.8
14. Target scope and cost are allocated to cross-functional TVD teams, typically by facility system; e.g., structural, mechanical, electrical, exterior, interiors, …	4.8	4	5	.5
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.	4.4	3	5	.9
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.	4.4	3	5	.9
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.	5	5	5	0
18. Set-Based Design was used in the design stage.	4	3	5	1
19. Choosing By Advantages was used to select between alternatives.	4.8	4	5	.5
20. A3s were used to document design alternatives.	4.8	4	5	.5
21. A3s were used to solve problems.	4.4	4	5	.5
TVD SCORE (%)	85.7%			

Out of the 21 questions, five questions had a mean score of less than 4.0 and five had a mean score greater than 4.5. For the questions with low scores, our goal is to determine why the respondents believe that the benchmark was not achieved. For the questions high scores, our goal is to collect evidence to show how these benchmarks were accomplished on the project and report these practices. There are five questions with a standard deviation greater than 1. The relatively high standard deviation suggests that there is a disagreement between the respondents about the degree to which a benchmark was achieved. Our goal for the questions with the high standard deviation is to investigate the root cause of this disagreement.

The questions with scores lower than 4.0 are: question 1, question 2, question 3, question 5, and question 9. Questions 1, 2, 3, and 5 all pertain to the business plan, validation study, setting the target cost based on the business plan, and developing the target cost with the key participants. According to the interviewees, the owner did not involve all the key trades in the development of the target cost and the business plan. The history of the project shows that the owner engaged with 3 teams each consisting of an architect and a general contractor for a design competition. The results of the design competition and the owner's financial constraints formed the basis for the business plan, the target scope, and the target cost. It appears that some of the trade partners that entered the project later during the design phase were not as informed about the basis of the target cost.

Question 9 had the highest standard deviation and the biggest range with the owner giving a score of 5 and a trade partner giving a score of 1. Based on the interviews that were conducted after the survey and other sources of data, we believe that some people may have interpreted the question incorrectly. The data revealed that the cost and schedule objectives were accomplished. The only major changes in scope were the addition of a cardiovascular center and a helipad initiated by the owner. The Target Cost increased by $7 million for the cardiovascular center and $500,000 for the helipad.

The questions with standard deviations greater than 1.0 include: question 2, question 3, question 5, question 6, and question 9. The reason for the high standard deviations for questions 2, 3, 5, and 9 were explained in the previous section. Question 6 pertains to the owner's role and commitment to be a permanent and active participant in the project delivery. Only one survey respondent rated a low score while all the other respondents rated a high score for this question. The follow-up interviews revealed that the owner was very actively involved in the project and most likely the high standard deviation observed in this question is due to noise that arises from analyzing data from such a small sample size.

3.3.4 Target Value Design Research Group Meeting

The UC Berkeley's Target Value Design Research Group includes 12 members within the Northern California AEC industry including: a general contractor, MEP trade partners, architects, electrical engineer, structural engineers, and specialty contractors. The TVD Research Group was formed in 2010 with the goal of improving TVD and Lean application on design and construction projects. In 2010, TVD and IPD were fairly new concepts and the group wanted to learn from and improve their Lean project delivery. Since the inception of the group, the members met regularly with the researchers from UC Berkeley to discuss findings on their case study projects. These research meeting took place every 2-3 months, typically on a Friday and lasted from 10am to 2pm. The researchers from UC Berkeley would present new findings on the five case study project (including the Temecula Valley project) and the people who were involved on the project would be engage in the discussion, clarify the issue, and correct any misunderstanding. By using the TVD Research meetings as a forum, this research benefited from: (1) ensuring that the research questions were relevant to the industry, (2) leveraging the experiences of industry practitioners in the development of the research, (3) gathering rapid feedback on the findings, and (4) having the people involved on the project to ensure the accuracy of the findings.

4 Research Findings

4.1 Project History

Founded in 1981, UHS is one of the largest healthcare providers in the United States with approximately $8 billion of revenue annually (UHS, 2012). They are organized as a non-profit organization and provide services in Washington D.C., Puerto Rico, and the U.S. Virgin Islands (UHS, 2012). In 2012, UHS spent $363 million on capital expenditures, which includes renovations of existing buildings and new construction of healthcare facilities (UHS, 2012). In California, UHS has 7 hospitals dedicated to Behavioral Health Services, 5 hospitals dedicated to acute care services, and one ambulatory surgery center (Surgery Center at the Temecula Valley) (UHS, 2014). Annually, they commission over 100 construction projects – most of these projects are small renovation projects but there are several large-scale construction projects as well (Seed, 2013).

UHS started using Lean after hearing about the success from Sutter Health, Inc. at a conference in March of 2007. They contacted Greg Howell from Lean Project Consulting, Inc. to help them get started on their Lean journey. Since 2007, UHS has completed over 40 Lean IPD and TVD projects and have 60 projects in development/construction (Seed, 2014). Out of their 40 completed Lean IPD and TVD projects, they have not had any major problems and are very happy with the outcomes. These projects have typically been completed 10% to 30% below market price (Seed, 2014). For the Temecula Valley project, UHS also expected to achieve the same outcomes, implementing lean from the beginning of the project.

The project was originally designed in 2008. It was re-assessed in late 2009 at which point UHS realized that the cost was more than they can afford. At that time, the owner (UHS) had developed a business plan based on market research of the area's demographic to determine their anticipated revenues from the hospital services. If they could not build the project within their cost constraint, the project would not proceed any further. The re-assessment process started with 3 teams each composed of one architect and one contractor. The teams were tasked with developing a design that could be completed for 30% below historical cost benchmarks for a California hospital. The 30% stretch goal was created by the owner to meet their budget constraints and was based on their assessment of potential increases in efficiency by using IPD. The combination of UHS's internal budget for the project and the design proposals (including the challenge to develop a design that is 30% below the California cost benchmarks) formed the basis for the target cost. After reviewing the proposals, UHS decided that two of the teams had good ideas that they wanted to incorporate into the project and had the two GCs and two architects form a joint venture. In the construction industry it is more common for GCs to form a Joint Venture than for architects to do so. At the end of the schematic design, HMC remained as the architect since the difficulties of organizing and integrating two architects was greater than its benefits. DPR and Turner formed a Joint Venture as the General Contractor. Besides the design proposals, there were no other formal validation studies conducted for the project.

4.1.1 Lean Training at Temecula Valley

Kristin Hill from Inside Out Consulting was involved for 7 months during the design phase. She first came onboard in Q4 2010 when the project cost was at its highest point. She left the project in Q2 2011 just before the start of construction. Her role as a Lean Construction coach was to: (1) help the team develop their TVD process, (2) to teach Lean Construction methods, tools, and concepts, and (3) to help the team become self-sufficient in continuing the Lean culture. During the construction phase, the Lean training was a joint effort by Turner, DPR, Southland, and UHS. Each person who joined the project (project managers, project engineers, and field supervisors) had to go through an onboarding orientation, which covered the basics of Lean Construction, the project's culture, owner's goals, and the project's expectations. The onboarding orientations took place monthly or more frequently depending upon the needs of the project. In addition to the training, each member was also given an onboarding manual. For the field staff, there was a condensed version of the training, which lasted half a day. People who had not gone through the on boarding process could not attend the big room meetings.

4.1.2 Project Timeline

The TVD/IPD team entered the project in March of 2010 with a GMP contract. In April of 2010, the design was approved by the city council. In February of 2011, the TVD/IPD team signed the ConsensusDocs 300. Increment 1 & 2 OSHPD documents were submitted in February of 2011. The key dates for the construction phase include (Figure 4):

- Groundbreaking – June 2011
- Start of foundation work – August 2011
- Start of steel erection – November 2011
- Steel topped out – February 2012
- Roof deck placements – March 2012
- Project completion – August 2013
- Hospital open for the first patient – October 2013

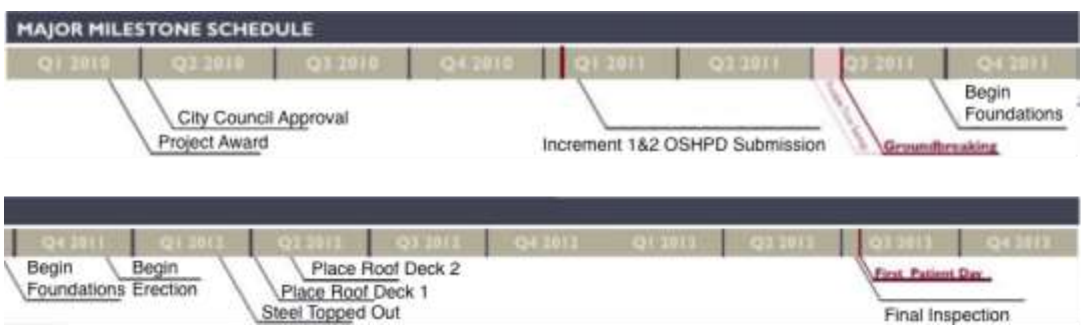

Figure 4: Major Milestone Schedule

4.1.3 Forming the Project Team

During the schematic design phase, DPR-Turner, HMC, and UHS used Choosing By Advantages (CBA; Suhr, 1999) to select the remaining TVD/IPD members. They determined the trades that would be the major drivers for the project (e.g., MEP, fire protection, drywall). The criterion for choosing the disciplines to include in the risk pool was: does the work have large impact on the success of the project? The impact on project success can be measured by high contract value, critical path work, or work that needs to be highly coordinated. They developed a shortlist of 3 to 5 trades for each discipline and evaluated the candidates based on the following factors: (1) company experience, (2) qualification of project staff, (3) proposed design solution, (4) BIM capabilities, and (5) QA/QC process. Part of the selection process included a discussion of the overhead, profit, and personnel billing hours of each discipline. The team members that were already selected vetted the numbers to make sure that they were consistent with the market rates. They did not conduct a formal audit for each company. The team used CBA[7] because they wanted a formal process to select the best company and the best people to work on the project.

Table 5. Choosing By Advantages Example

Factors	**Criteria**		**Design Assist Steel**					
			Company 1		Company 2		Company 3	
Company Experience	Must have high rise experience	**Attribute**	$400 to $500 MM company value. $150 M in Socal. Has in-house design capabilities through Jay.	Importance	$225 M company. $80 M in Socal. 1000 employees doing a very good job on the 49ers stadium	Importance	$500 M to $600 M value. They completed LA Live	Importance
		Advantage						
Staff Qualification	Strong project manager with DA Experience	**Attribute**	Jay is very qualified engineer. PX has local experience and foreman is very solid	Importance	Solid team. I see less depth on the design support	Importance	Bob, Lee, and Randy have good local experience	Importance
		Advantage						
Design Solutions	Ability to meet design requirements	**Attribute**	Jay offered an alternative that enables a 1.3' floor height reduction	Importance	Recommend the use of grade 65 steel. Generally not as strong on the design side	Importance	They have support many of the design solutions that have been studied to date.	Importance
		Advantage						
Project Approach	Innovative ideas such as prefabrication	**Attribute**	Very active design assist team. Very solid understanding of the schedule requirements	Importance	Can improve the schedule by 1 month. Solid experience builder	Importance	Will buy plates overseas and fabricate either in CA or Asia	Importance
		Advantage						
Proposal	Complete proposal with reasonable assumptions and clearly defined exceptions	**Attribute**	They have the labor risk and use limited risk on shapes	Importance	Have price protection through Nucour	Importance	Lead the proposal development process	Importance
		Advantage						
Value Ideas	Provide innovative design and	**Attribute**	Use cable brace at column support. Use cap	Importance	Use a shipbuilder to fabricate	Importance	Propose linking the steel,	Importance

[7] Note that CBA, like Best Value Selection processes, separates qualifications and cost, but CBA does not weight qualification criteria or cost and Best Value Selection processes do.

	construction solutions		plates at column splices		the plates. The ship builder is offering $4.5 M in savings		concrete, decking, and curtain wall through a GMP with savings participation	
		Advantage						
BIM Capabilities	BIM capabilities for design development, clash detection, and as-built drawings	**Attribute**	5 modelers in-house use of etabs, tekla, navis	Importance	In house modeling and detailing. Has been 100% BIM for fabrication for the past 10 years	Importance	Full modeling capabilities	Importance
		Advantage						
QA/QC Process	Well defined QA/QC process	**Attribute**	Will QC any offshore purchased material	Importance	Full QC in the shop with 3rd party Nasco	Importance	Will provide QC for any offshore materials and utilize third party inspections	Importance
		Advantage						
Importance of Advantages								
Cost								

The 7 members that formed the TVD/IPD team included:

- Owner – Universal Health Services
- Architect – HMC Architects
- General Contractor – DPR-Turner Joint Venture
- Electrical Design Assist Contractor – Bergelectric
- Mechanical and Plumbing Design Assist Contractor – Southland Industries
- Drywall and Framing Contractor – DPR Drywall
- Fire Protection Design Assist Contractor – Southwest Fire Protection

Figure 5 shows the onboarding schedule for the both the members within the risk pool and the members outside the risk pool. This figure was taken from an internal presentation and is presented without modifications.

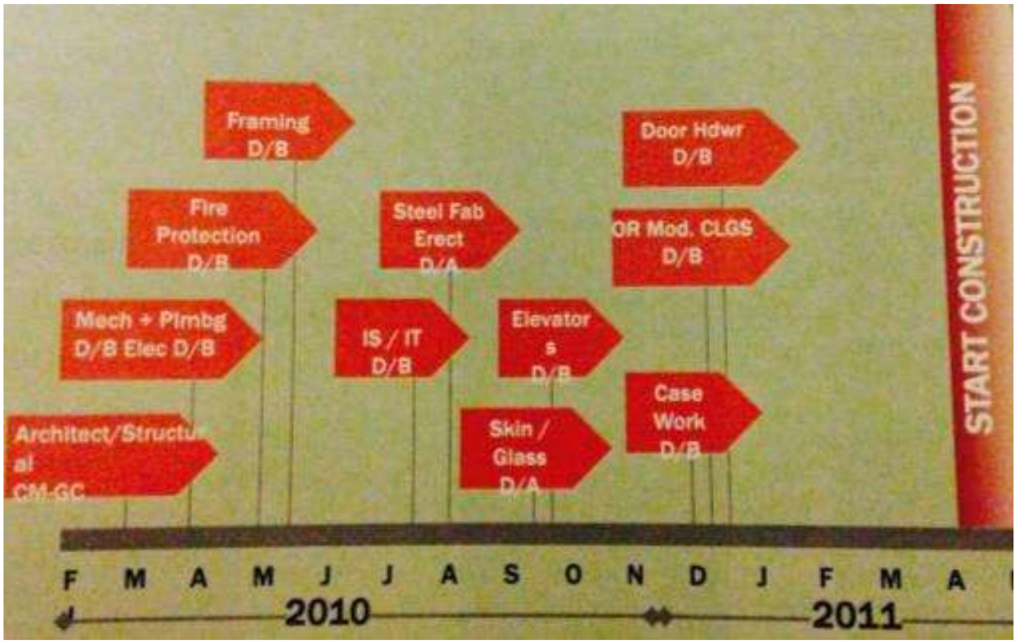

Figure 5: Onboarding of Team Members

4.1.4 Contractual Structure

During the design stage of the project, which lasted from March of 2010 until February of 2011, the TVD/IPD team was paid a not-to-exceed time and materials contract. In February 2011, the team signed the ConsensusDocs 300, which then covered both the construction and design phase and superseded the prior agreement. The ConsensusDocs 300 is a relational contract inspired by the Integrated Form of Agreement (IFOA) (Lichtig, 2005; ConsensusDocs, 2013). The ConsensusDocs series of contracts were developed by a coalition of 36 members from the construction industry including: “Design Professionals, Owners, Constructors, Subcontractors, and Sureties [to] literally spell the [word] DOCS in ConsensusDocs” (ConsensusDocs, 2013). The goal of the coalition was to create a set of contracts that fairly allocates risks and do not unjustly favor one party over another (ConsensusDocs, 2013).

The ConsensusDocs 300 includes terms that stipulate: (1) the use of Lean Construction principles, (2) a Management Group composed of the IPD members, (3) Target Value Design is used to ensure that cost and schedule constraints are taken into account by designers, (4) pain/gain sharing between the IPD members, (5) cost of work is reimbursed, with open book accounting practices (e.g., the right to audit), and (6) disputes are resolved collaboratively by the Management Group (ConsensusDocs, 2013). UHS made minimal modifications to the contract template and only altered the agreement to allow for 7 parties instead of the original tri-party agreement. The 7 members of the TVD/IPD team signed the ConsensusDocs 300 in February of 2011 (Figure 6). According to the Temecula Valley team, the signing of the contract was a “symbolic event” with all the key members present – there was no mailing in of signatures.

Figure 6: ConsensusDocs 300

4.2 Project Definition

4.2.1 Business Case

The business case for the Temecula Valley project was developed by UHS based on their market research and the anticipated revenues from the hospital over its lifetime. The business case reflected the fact that the hospital is in a rural region of Southern California, the demographics of the area, and new healthcare legislation in the United States (The Affordability Care Act), which will impact future revenues. The initial cost estimate for the project was $149.4 million dollars for 140 patient beds. The Target Cost was set at $144 million dollars, which is an average of $1.1 million/patient bed, substantially under the average for California hospitals of $1.8 million/patient bed.[8]

4.2.2 Stakeholder Values

The programming for the hospital called for 140 patient beds (120 medical/surgical and 20 ICU). All of the beds had to be private rooms with their own window view. The program also includes: (a) an emergency department, (b) six operating rooms, (c) one minor procedure room, and (d) a helipad. The only major changes to the scope of the project were a $6.8 million cardiovascular center that was added in late 2011 and a $500,000 helipad. The addition of the cardiovascular center and the helipad increased the Target Cost from $144 million to $151 million.

During programming and schematic design, the team collected inputs from a number of internal and external stakeholders to gather requirements and inform the design. Figure 7shows the different groups of stakeholders involved in the program development.

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[8] The average $1.8 million cost per bed includes all hospitals in California, with no adjustment for size, functionality or location. It is also relevant to note that this metric is becoming less useful as the average duration of patient stays in hospitals decreases.

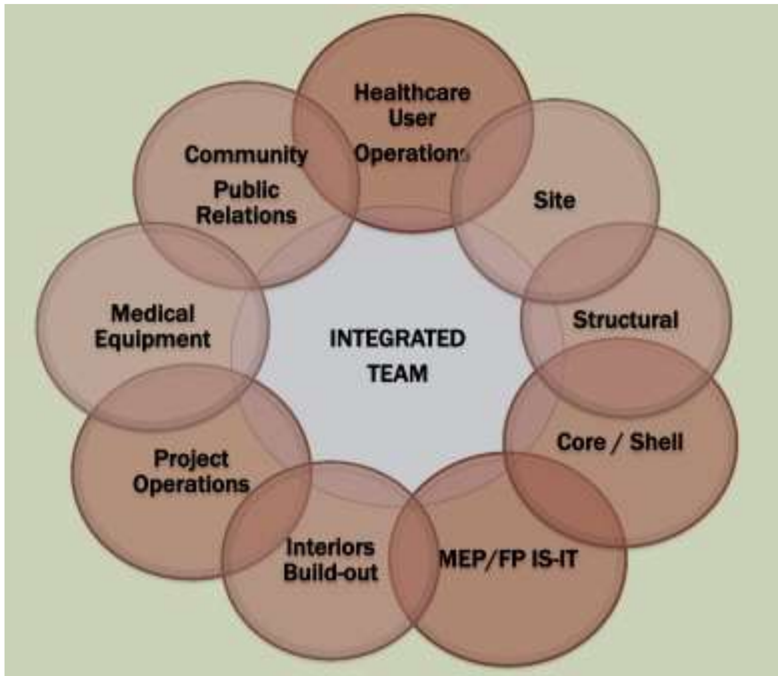

Figure 7: Integrated Team

The vision for Temecula Valley Hospital is "to deliver exceptional and compassionate patient care". To achieve this vision, the requirements for the hospital project included:

- 140 patient beds with the ability to expand to 320 beds in the future
- 24-hour visiting
- 28 private treatment rooms for outpatient services
- 20 intensive care unit (ICU) beds
- High-tech surgical suites and a minor procedure room
- Cardiac catheterization laboratory
- Cardiovascular operating room
- Central operations center
- In-room computer workstations for timely and accurate documentation
- 100 percent electronic medical records, in-room charting, and other technology enablers
- Training room for technology
- 24-hour room service for patients
- In-room physical therapy
- Full-service kitchen with seating for 100
- Ample parking for patients, visitors, physicians, and employees
- Final build out entitled for up to three medical office buildings

The key patient-care features included:

- Optimum lighting levels
- Noise reduction strategies (operational and architectural)
- Care areas designed to minimize walking distances for staff
- Room-service dining and guest trays for visitors
- Bistro-style coffee shop
- Outdoor dining
- Home-like waiting areas

- Family sleep zone
- Local art

4.2.3 Conditions of Satisfaction

UHS established the following conditions of satisfaction:

1) Project Delivery Success

- Maintain Conditional Use Permit by securing major modification approval in November 2010
- Maintain or reduce the Target Value Cost of $144M for 140 beds
- Deliver the Owner's Manual six months prior to opening (approximately 3rd quarter 2012)
- Certificate of Occupancy by the 1st quarter of 2013
- Construction safety

2) Project Team Participation and Satisfaction

- Every team member firm finishes this project with a profit
- Predictable outcomes as a result of labor efficiency
- Reliability and trust as shown by measuring promises made versus promises kept

3) Community and Social Responsibility

- Positive press in the local and regional press
- Physician buy-in as reflected by hiring rates
- Neighborhood satisfaction – survey to be conducted

4) Relationships with Regulatory Agencies

- Maintain promise of UHS being OSHPDs best customer
- Zero defects in all agency submittals
- Drawings in OSHPD possession for a time period 15% lower than the lowest established records
- "No excuses" surrounding OSHPD, City, etc. for not meeting COS, milestones, etc.
- Trade partners considered a business partner of OSHPD at the completion of the project

5) Facility Operational Success

- 30% more operationally efficient than the best performing UHS facility
- Patient Family Centered Care Delivery and Design reflected by HCAHPS scores[9].
- Safe Patient Care Environment
- Community endorsement by the use of our facilities versus others in the area

4.2.4 Target Setting

"Recognizing a need for healthcare services in the Temecula Valley, UHS embarked on a traditional design-bid-build process in 2005 to construct a new hospital in Temecula. The hospital was first designed by a Texas-based architectural firm in 2006 with 173 beds and expansion capability up to 320 licensed beds using a reinforced concrete and precast structure. The plans were submitted to the Office of Statewide Health & Planning Development (OSHPD) in 2007 and approved in 2008. The design received

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[9] http://www.hcahpsonline.org/StarRatings.aspx

approval from the City of Temecula ('entitlements'), an environmental impact review was conducted, and construction drawings were completed. The project was placed on hold in 2008 when the economy slowed and the population growth in the community was predicted to decrease. In the meantime, the City entitlement expiration date grew closer and OSHPD approval of a similar project with precast concrete encountered challenges and delays. The Temecula Valley Hospital project was revived in December of 2009 with a concept for a smaller hospital that did not require precast concrete. UHS issued a request for qualifications to three design firms, asking them to select contractors to form self-directed teams to validate the new concept." (UHS, 2014)

The target cost was set by three different requirements: (1) UHS' anticipated revenues from the area, (2) UHS' limited budget for the project, and (3) UHS' challenge to the three design teams to develop a concept that is 30% below the historic market average. UHS believed that they could delivery the project well below the market average because the team would be integrated and thus be able to reduce waste in traditional project delivery systems. Due to UHS' limited funds for the Temecula Valley project, there would be no project if none of the teams can develop a concept that is within their requirements.

The original[10] target cost of $144 million was a result of the design competition. At the end of the design competition, the concept from the Turner team was chosen by UHS as the most economical approach. Turner validated the Target Cost with a financial benchmark of their historic urban and green field hospital construction (Figure 8 and Figure 9). The team kept the estimate dynamic and updated it on a weekly basis.

"There might be one section of the estimate that needed to be revised and so we updated it. Maybe the next week, there was a discussion on the structural system. We have a variance every week. We would do a total project re-estimate every 6 weeks. We used the models to pull out quantities." – General Contractor

[10] The initial target cost did not include the cardiovascular center and the helipad.

Turner

Benchmark Comparison

Cost Summary	Large Urban Hospitals		Small Greenfield Hospitals		UHS Temecula I Occupancy Target Estimate	
	Building Area: 177,637 gsf		Building Area: 177,637 gsf		Building Area: 177,637 gsf	
	Estimate / GMP Date: 1/1/2011		Estimate / GMP Date: 1/1/2011		Estimate / GMP Date: 1/1/2011	
	Escalated to 1/1/2011		Escalated to 1/1/2011		Escalated to 1/1/2011	
	Totals	Unit Costs	Totals	Unit Costs	Totals	Unit Costs
Demolition & Patching	$2,893,058	$16.29	$281,091	$1.58	$0	$0.00
Excavation & Foundations	$6,421,550	$36.15	$6,562,845	$36.95	$3,318,722	$18.68
Structural Frame	$12,533,960	$70.56	$8,732,233	$49.16	$8,096,264	$45.58
Roofing & Waterproofing	$2,323,624	$13.08	$1,494,016	$8.41	$1,389,895	$7.82
Exterior Wall	$6,839,998	$38.51	$3,901,268	$21.96	$4,208,606	$23.69
Interior Finishes & Partitions	$21,610,060	$121.65	$17,594,759	$99.05	$16,734,383	$94.21
Special Requirements/Equip.	$1,924,435	$10.83	$792,860	$4.46	$1,682,726	$9.47
Vertical Transportation	$2,400,695	$13.51	$886,417	$4.99	$1,340,700	$7.55
Fire Protection	$1,354,778	$7.63	$1,476,381	$8.31	$1,295,131	$7.29
Plumbing	$9,067,146	$51.04	$7,237,433	$40.74	$13,252,850	$74.61
HVAC	$13,529,127	$76.16	$12,296,285	$69.22	$12,658,463	$71.26
Electrical	$14,325,122	$80.64	$11,579,199	$65.18	$12,897,600	$72.61
Subtotal Building	$95,223,555	$536.06	$72,834,787	$410.02	$76,875,340	$432.77
Sitework	$0	$0.00	$0	$0.00	$0	$0.00
Tenant Finishes	$0	$0.00	$0	$0.00	$0	$0.00
Subtotal	$95,223,555	$536.06	$72,834,787	$410.02	$76,875,340	$432.77
P&P Bond	$1,122,637	$6.32	$480,935	$2.71	$0	$0.00
Construction Contingency	$3,782,388	$21.29	$1,543,233	$8.69	$3,670,667	$20.66
General Conditions	$11,373,827	$64.03	$7,745,518	$43.60	$4,251,000	$23.93
General Requirements	$2,889,724	$16.27	$2,485,451	$13.99	$2,585,571	$14.56
Insurance	$2,489,645	$14.02	$1,128,932	$6.36	$2,649,917	$14.92
Subguard	$461,201	$2.60	$0	$0.00	$0	$0.00
Fee	$3,501,473	$19.71	$2,935,132	$16.52	$2,943,456	$16.57
Combined Markups	$25,620,895	$144.23	$16,319,200	$91.87	$16,100,611	$90.64
Total Cost	$120,844,450	$680.29	$89,153,987	$501.89	$92,975,951	$523.40

Figure 8: Cost Benchmarking

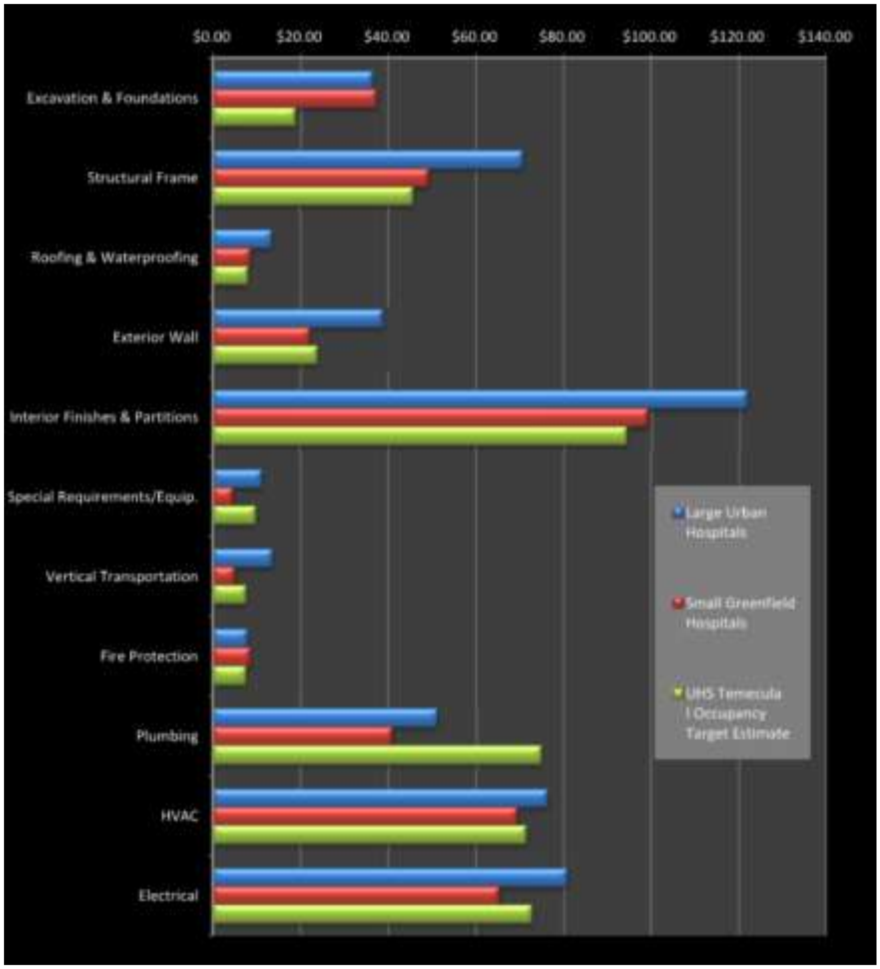


Figure 9: Components of Cost Model

Figure 10 shows how project costs were broken down. From the total estimated cost of work ($149.358.000) the TVD/IPD team carried 83%. The remaining 17% were contracted out to GMP and Lump Sum trade partners. The contingency was set at ~3% of the project cost and is significantly lower than on projects that do not use TVD/IPD (Do et al., 2014).

As part of the agreement, cost overruns first come out of the team's contingency and profit pool. The owner will pay for all cost of work (no profit) beyond the depletion of the contingency and risk pool. Any savings will be shared 50/50 between the TVD/IPD team members (i.e., risk pool members) and the owner. The team is able to earn up to 150% of their negotiated profits with any additional savings beyond 150% of their profit returned to the owner. During the project, the owner reimburses the team based on their cost of work[11] (i.e., actual invoices) and anticipated profits are dispersed to the team at regular intervals. Out of the $116 MM of work that was to be performed by the risk pool members, their negotiated profit was $4.2 MM[12] and $4.4 MM was set for the project contingency. The project

[11] Cost of work includes all the direct and indirect cost for the companies inside the risk pool. Direct cost includes personnel salaries, medical insurance for workers, and retirement fund contribution. Indirect cost includes corporate overhead (marketing, accounting, etc.)

[12] In accounting terms, the negotiated profit for the risk pool members is the net profit. The firm's overhead costs are included in their cost of work (Figure 10).

contingency was a fix amount of money allocated to absorb unanticipated problems (e.g., differing site conditions, environmental impacts, unanticipated escalations, design mistakes). Any money that was not spent from the team's contingency pool would become part of their shared profit. Material and labor escalations were included in the cost of work as a line item. Parties outside the risk pool performed the remainder of the work ($24.4 MM).

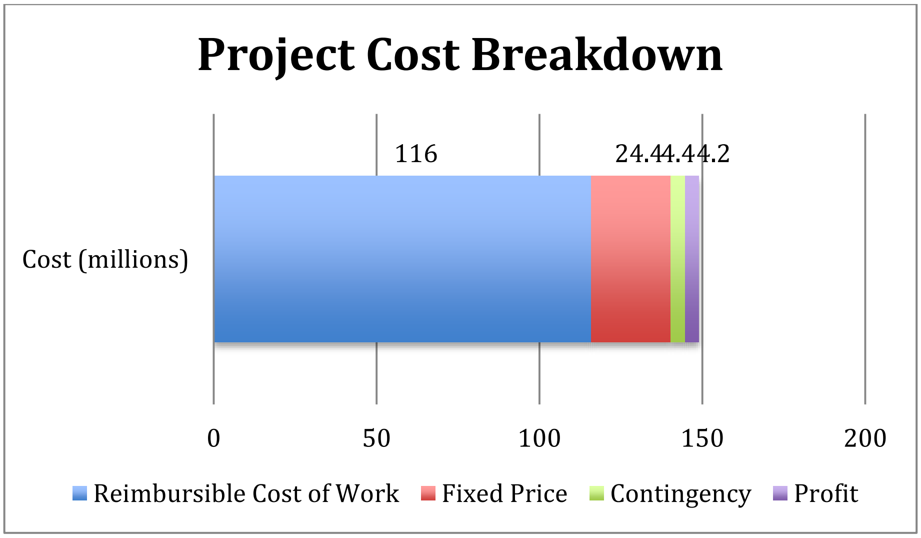


Figure 10: Initial Target Cost ($151 million)

The Interviewees provided several reasons for a lower contingency:

- Since the contractors are involved in the design phase and the team is steering the design towards a Target Cost, there is less risk of cost overruns.
- The project team members pooled their contingency together and therefore less contingency was needed to cover the same amount of risk.

The project contingency covered: (1) errors and omissions, (2) rework, and (3) escalation of labor and materials. By the time of signing the Consensus Docs 300, the team had already completed most of their construction documents and had already locked in the prices for their materials (e.g., steel, conduits, pipes) so there was less risk of escalation. Since the construction phase was relatively quick (14 months total), it was possible for the Temecula team to lock in the prices of their most essential materials. For projects with much longer durations, there may be the question as to who bears the risk of material escalation. Standard practice is to carry a separate contingency for escalation, and maintain it as long as the team as a whole, owner included, consider it to be needed.

Each company had a negotiated profit based on their respective business models[13]. The profit for the whole TVD/IPD team was fixed and they placed 100% of it into the risk pool. The total profit pool is the summation of each company's negotiated profit times their total cost of work ($Profit_{total} = \sum_{i=1}^{n} Cost\ of\ Work_i \times Negotiated\ Profit_i$). Table 6 shows the percentage of the risk pool for each of the companies. Note that although Southwest Fire only held 1.5% of the risk pool profits, they were included as a TVD/IPD member because their scope of work is critical to the success of the project and highly interdependent with other trades.

[13] The exact profit margins of each company are not listed in this report for confidentiality reasons.

Table 6: Percentage in Risk Pool

Company	Percentage in the Risk Pool
HMC	17.9%
DPR/Turner JV	30.5%
Southland	25.7%
Bergelectric	14.6%
Southwest Fire	1.5%
DPR Drywall	9.8%
Total	100%

4.2.5 Expected Cost During Design and Construction

Figure 11 shows the expected cost of the project throughout the design and construction phase.

Figure 11: Expected Cost Throughout the Project

Figure 12 shows the expected profit of the team. The team tracked the expected profit during construction. The black area indicates the amount of profit that had been realized.

When the joint venture was formed in January 2010, there was a $5 MM gap between the expected cost ($149 MM) and the target cost ($144 MM). This gap corresponded to about 3.5% of the target cost (Figure 11). When the major trade partners onboarded the project in Q1 and Q2 of 2010, the gap between the expected cost and the target cost had grown to $9 MM. The root causes of the increase in the expected cost are documented in Figure 53. In Q2 and Q3 of 2010, it was uncertain if the team could achieve the Target Cost. Bill Seed's (VP of construction from UHS) leadership was instrumental in keeping the team together and getting them to focus on driving the design to the Target Cost. Confident that the team would be able to achieve the Target Cost, UHS continued to develop the design. By the beginning of 2011, the TVD/IPD team's estimate was still above their Target Cost but they were heading in the right direction. In February of 2011, the gap between the estimated cost and the Target Cost was $7 million. And although there was still a ~5% gap to close, the team and the owner trusted each other and believed that if they continue with their Lean processes, they should be able to close the gap and ensure that all the members earn a profit. This was a leap of faith for both the owner and the team. If the project was to be completed at the estimated cost, the team would earn zero profit and the owner would have to pay more than their allowable cost. It is important to note that both the owner and the team were well aware of the financial situation when they signed the multi-party contract. In 2010, the state of California was in a recession caused by the housing bubble. There were not many projects at the time, which is why the team was willing to sign the multi-party contract because it would allow them to keep their employees.

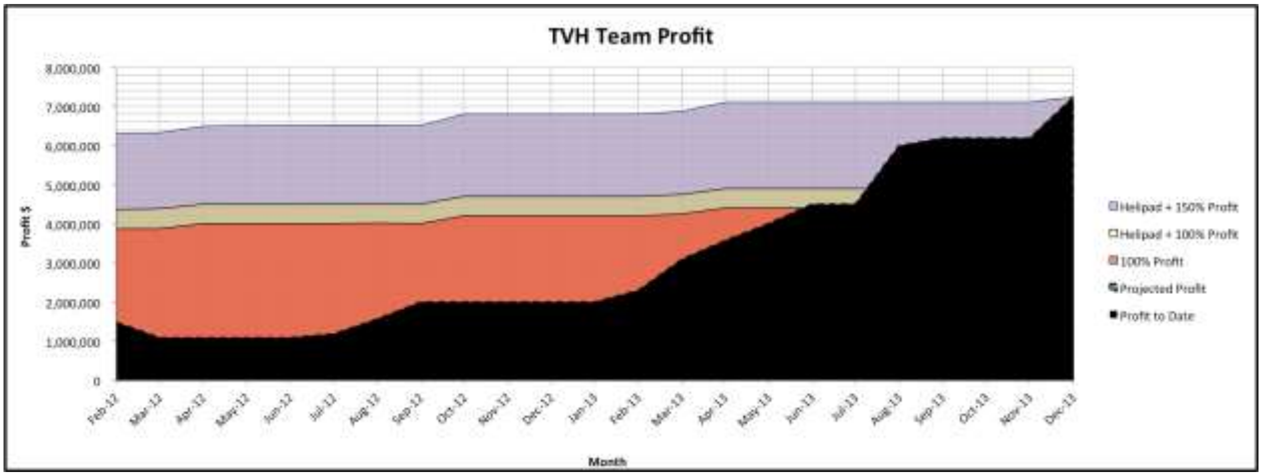


Figure 12: Expected Profit (Tracked During Construction)

4.3 Steering to Targets During Design

4.3.1 Cross-functional Teams For Design

The project teams were organized into 7 cross-functional clusters (Figure 13). The clusters allowed for efficient communication within the cluster group and dispersed the decision-making to the cluster and cluster leads. For example, MEP, Fire Protection, and Information Technology trades were placed in the same cluster because there is high level of interaction and coordination between these trades. The cross-functional clusters were:

- MEP/Fire Protection/ Information Technology
- Schedule/Project Systems/Agencies
- Core/Shell/Envelope
- Planning/Operations/Architecture
- Site/Community
- Budget
- Core Croup

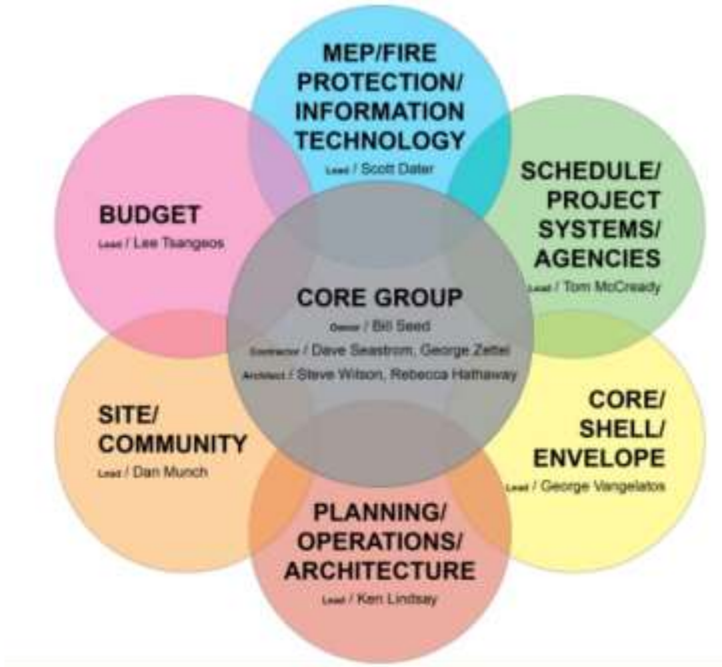


Figure 13: Cluster Groups

The team's guiding principle for the project was to: (1) have trusted, qualified, and profitable partners, (2) provide a creative and innovative environment, and (3) make learning a priority. Early on, the team identified events or activities that can have a major impact on cost, permitting, and schedule. After these activities were identified, cross-functional teams were created to focus on them. The goal of their cluster groups was to be "problem" focused. It was okay to assemble or re-assemble the cluster groups as needed. For example, when the core/shell group was no longer needed, they dismantled the group so that people could focus in other areas. They kept reassessing the necessity of the cluster groups. According to one interviewee, "the tricky part was making sure that each of those clusters were communicating with other clusters and reporting the information in Big Room meeting".

For the majority of the design phase, the integrated team was divided into 7 clusters (Figure 13). Each of the clusters was responsible to deliver their scope of work within their part of the project target cost, but both scope and money could move across clusters when doing so improved total project performance. Each cluster had a designated cluster lead responsible for decision-making and conflict resolution within his or her cluster. The core group, which consists of representatives from the owner, contractor, and architect, managed issues that relate to more than one cluster. In terms of decision-making and conflict resolution, most decisions were made at the cluster level or individual level. The core group only intervenes in situations that could not be resolved or in situations where there is a major impact (e.g., schedule, cost, quality).

The organizational structure promotes the flow of communication between the cluster groups and the core group (Figure 14). There were no legal or contractual boundaries that inhibited communication.

Figure 14 and Figure 15 show the interaction between the integrated team and the clusters. The integrated team is composed of the cluster leader. Both the integrated team and the cluster groups held regular meetings throughout the project. The integrated team met less frequently than the cluster groups (2x per week vs. daily). After every 3 weeks, the teams have a dedicated session for reflections (Figure 14). To promote dialogue, they organize their reflections into: (1) start doing, (2) stop doing, and (3) keep doing.

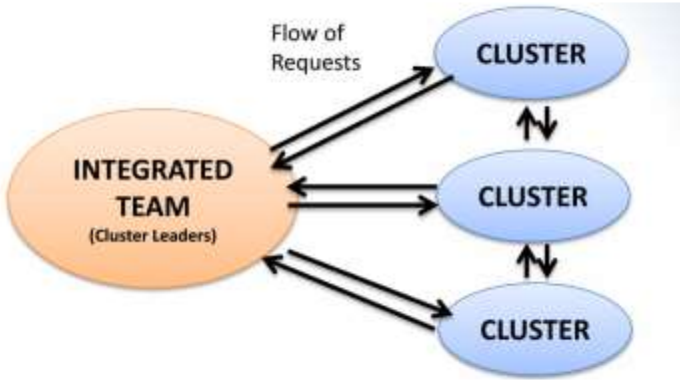


Figure 14: Flow of Requests and Communication

	INTEGRATED TEAM	CLUSTERS
Pull Plan Level	Macro	Micro
Check-ins Occur	2x per week	Daily or As-Needed
Milestones Come From	Master Schedule	Macro Pull Plan Commitments
Hand-offs Between	Cluster Leaders	Cluster Members
Break Down Work	1 week max	2 day max
Reflections	Every 3 weeks	Every 3 weeks

Figure 15: Role of Integrated Team and Clusters

Figure 16 shows a typical daily check-ins and meeting schedules for the clusters and the core team. On Tuesdays, the integrated team (i.e., cluster leaders) would meet and conduct a macro-level pull plan for the project. Based upon the commitments of the cluster leaders on Tuesday, each cluster group would update their micro-level pull plan.

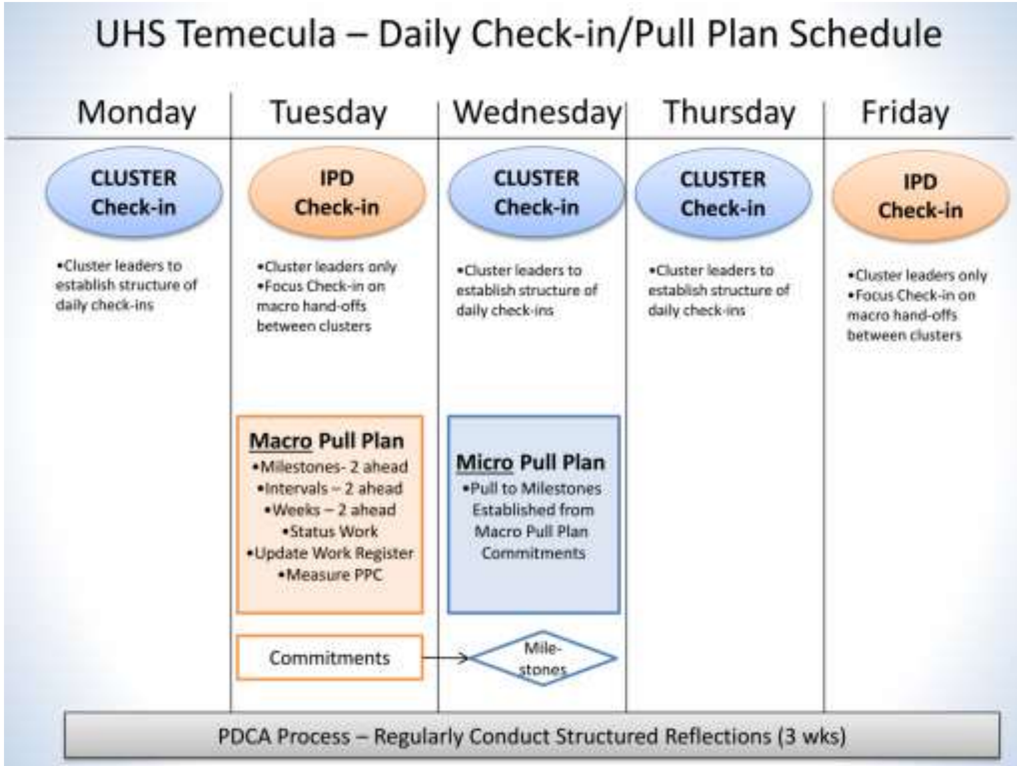


Figure 16: Daily Check-ins and Meeting Schedules

One goal of the project organization is to place the responsibility for design, estimate, schedule, and construction within each cluster group. The integrated team aggregates the data from the clusters to create the project budget and schedule. This practice avoids breakdowns and miscommunications (Figure 17).

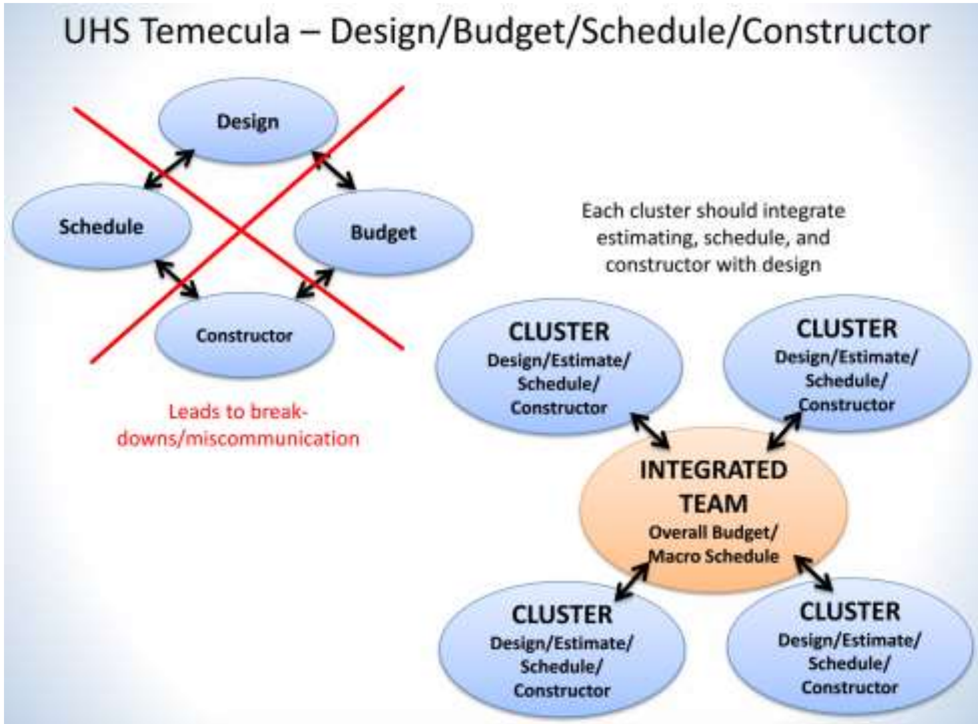


Figure 17: Design, Estimate, Schedule, Construction Responsibilities within Clusters

4.3.2 Integrated Governance

The integrated governance structure includes four distinct roles: (1) core group, (2) community of practice, (3) cluster leaders, and (4) cluster members (Figure 18; Figure 19).

The core group consisted of the members from the owner, contractor and architect. Their role is to coordinate, manage the overall day-to-day work, and ensure that the project is being delivered according to Target Value Design and Integrated Project Delivery principles. The core group had regular meetings and was ultimately responsible for solving problems that could not be resolved by the cluster teams. They signed off on major design decisions including decisions that required CBA and A3 documentations.

The community of practice included members from the owner and TVD/IPD team. All members of the TVD/IPD had to have at least one representative within the community of practice[14]. The goal of the community of practice is to advance the team's application of Lean methods, tools, and behaviors. The members inside the community of practice held regular sessions dedicated to learning and sharing best practices.

[14] The only exception was Southwest Fire. They were a relatively small company and therefore could not have dedicated personnel involved in the community of practice.

Figure 18: Core Team and Community of Practices Roles

The roles of the cluster leaders and cluster members are summarized in figure 18. The cluster leader's main responsibilities are: (1) use pull planning to organize the work within the clusters, (2) ensure that commitments are being met, (3) verify to constraints within the clusters are removed, (4) ensure that the key topics/concerns of the clusters are included in the agenda of the integrated team meeting, (5) represent the cluster in the integrated meetings, (6) be involved in the on-boarding process, and (7) promote the use of Lean Construction methods, principles, and tools.

The members work with the cluster leaders on: (1) developing the pull plan, (2) ensuring that commitments are being met, (3) removing constraints, (4) developing the A3s for problem solving and decision-making, and (5) continuously learning and applying.

The integrated governance model ensures that the responsibility of work is distributed across the team members. For example, the cluster leaders are responsible for the onboarding process. This governance structure avoids bottlenecks in the decision-making process and gives more control to the people doing the work at the cluster level.

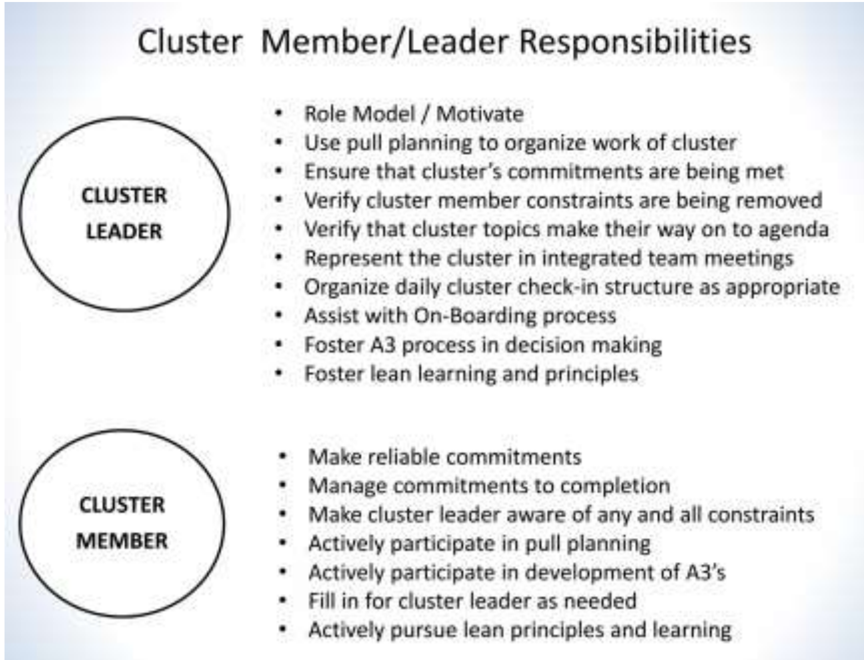


Figure 19: Cluster Leaders and Cluster Member's Responsibilities

4.3.3 Joint Responsibility and Transparency

As described earlier, the responsibility for the project was distributed amongst the members of the team via the cluster groups. Since the risk and reward was shared between the members, it makes sense that each of the partners had an "oar" to steer the ship. Joint responsibility and shared governance was very important in promoting a team environment. The organization of the team is centered on delivering the best possible results for the project. Figure 20 shows the members of this integrated team.

Figure 20: Integrated Team

Transparency was a key principle that was actively promoted on this project. All of the TVD/IPD team members had the right to audit each other's finances. The labor productivity and production rates were tracked and publicly displayed on-site (Figure 21). By displaying project Key Performance Indicators (KPIs) in accessible locations (e.g., in the trailer and on the job site), the people who needed the information could access it quickly. The practice of making the workplace "visual" reduced the number of times that people needed to ask for the information, which can be a time-consuming and expensive process. Miscommunication and miscoordination of information can be reduced by this practice.

Figure 21: Field Board at Temecula (Seed, 2014)

4.3.4 Co-location and Big Room Meetings

During the early stages of the project, the team developed several temporary big rooms. Overall the team shuffled between 3 big rooms before establishing a permanent space on-site. During the schematic design phase, the team had "big room" (aka integrated team) meeting every 2 weeks. These meetings occurred off-site at another project site in Corona, California. During the design development and construction document phase, the team had big room meetings twice a week on Tuesday and Wednesday at the Corona site. At the start of construction, the team was continuously co-located on-site and held formal "big room" meetings twice a week. Figure 22 and Figure 23 show the layout of the co-location at Temecula Valley.

Figure 22: Co-location Space (Temecula Valley)

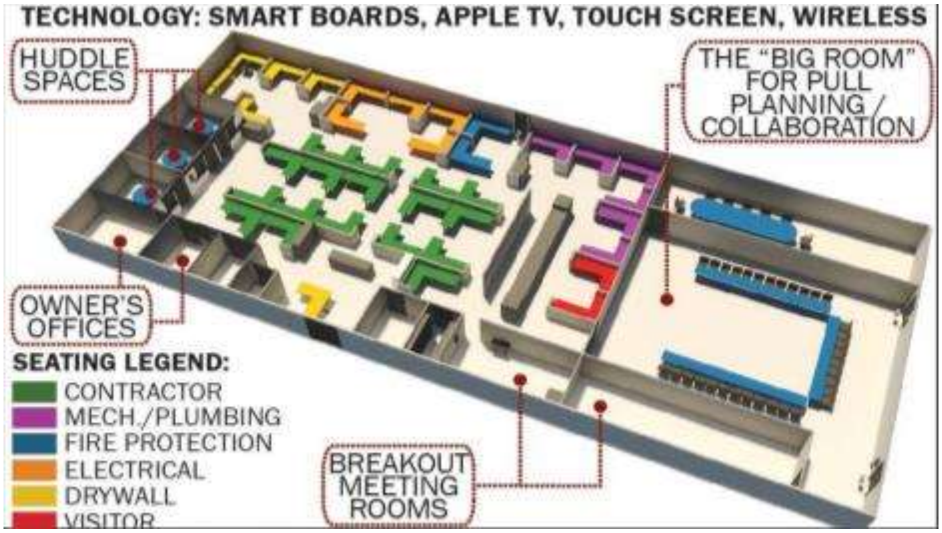


Figure 23: Co-location Trailer Layout (Temecula Valley)

In order to maximize the efficiency of the big room meeting, the TVD/IPD established several ground rules:

- **This is a Safe Zone**
- **Everyone is encouraged to speak his or her mind** without concern for embarrassment or ridicule by others.
- **We all have equal status and say in all matters**.
- **No one person has more authority than others.**
- **Speak up** - get engaged in conversation and share ideas.
- **Your opinion is important** in helping guide the team.
- **Listen to others** - focusing on what others have to say helps you understand their point of view.
- **No side conversations.**
- **Only have one meeting at a time.** Conversations should be heard and shared by all.
- Help keep the meeting and participants on track by **eliminating phone disruptions**.
- **No multi-tasking**. This includes laptop computers and PDA's.
- **Stay on time**. This includes start time, end time, break times and agenda

Figure 24 shows the layout of the team's scheduling software for the big room meetings. Some key components include: (1) big room facilitator, (2) color codes for breakout sessions within clusters, (3) timing of the meetings, (4) expected outcomes of the meeting, (5) attendees, and (6) contact information.

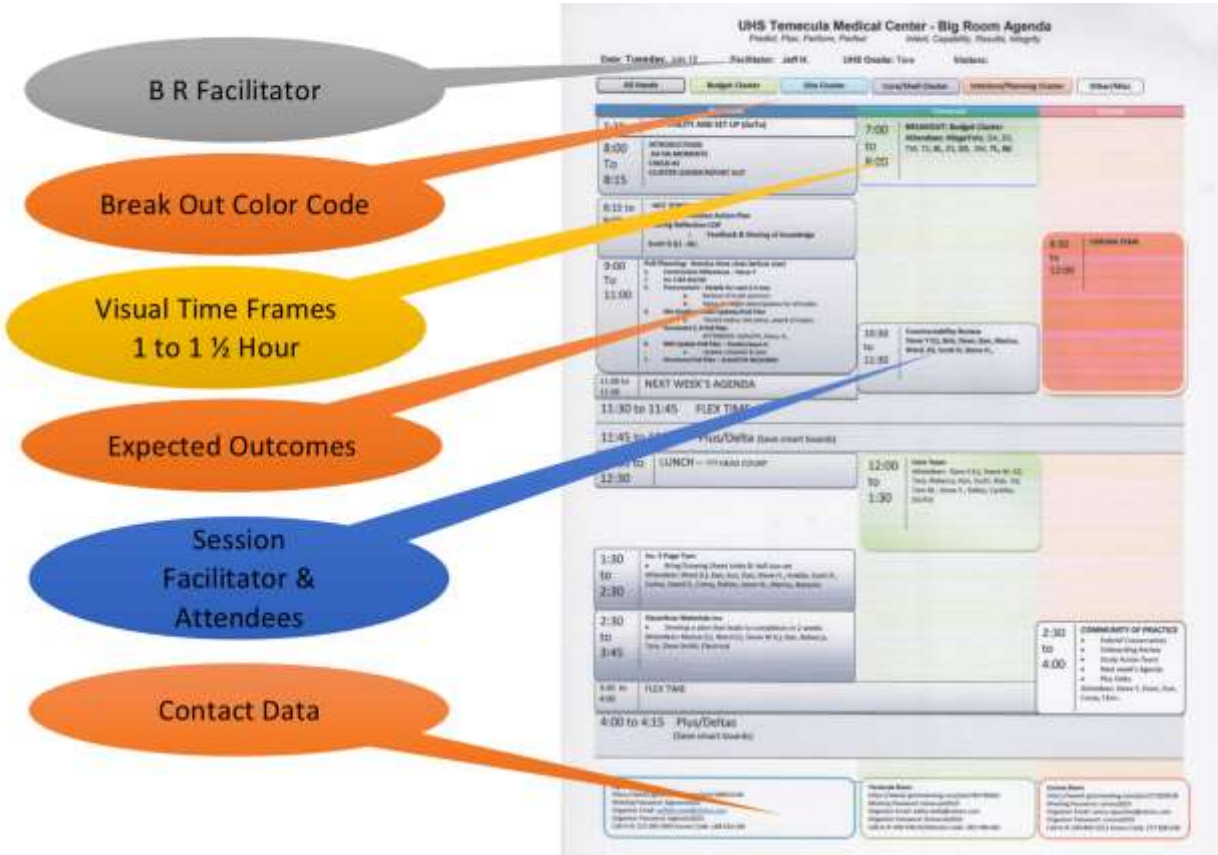


Figure 24: Big Room Meeting Scheduling Software

During DD and CD, the team held big room meetings on Tuesdays and Wednesdays. Tuesday's meeting was with the cluster group and breakout group. Wednesday's meeting was for the whole team. On Wednesdays, they would talk about their numbers (cost, schedule, and burn down rates), conduct pull planning, and identify lessons learned. During construction, they had 1 big room meeting per week for the key trades. The management team met 1 hour each week to go over elevated issues. Towards the end of the project the meetings got shorter and the cluster group was no longer needed during construction. Although the contents of the big room meetings varied through out the project's timeline, the team developed a structured approach for the meetings, which included (Figure 25):

1. **Introduction / Ice Breaking** - to get people comfortable with each other and breakdown barriers.
2. **AH Ha Moments** – something that happened that surprise you or something that came to you.
3. **Budget Reporting** - burn rate, status of the overall budget, review of saving items, review of risk items.
4. **Hot Topics** – items that came up from the daily check-ins, which needs to be addressed quickly in order to maintain schedule or budget constraints.
5. **Pull Planning** - sometimes there would be multiple pull plans being done in the same day with different cluster groups.
6. **Community of Practice / Time Reserve for Learning** – they would invite someone outside to come in to present to the group. This person could be a vendor or person knowledgeable about a topic. Additionally they would send two people from the project to visit another job and presented what they learned. Sometimes, they would have people within the group present their lean practices or innovations.
7. **Break out groups** (rest of the day).

8. **Plus/Deltas** – the plus deltas were conducted in the morning (before lunch) and in the afternoon (at the end of the day).

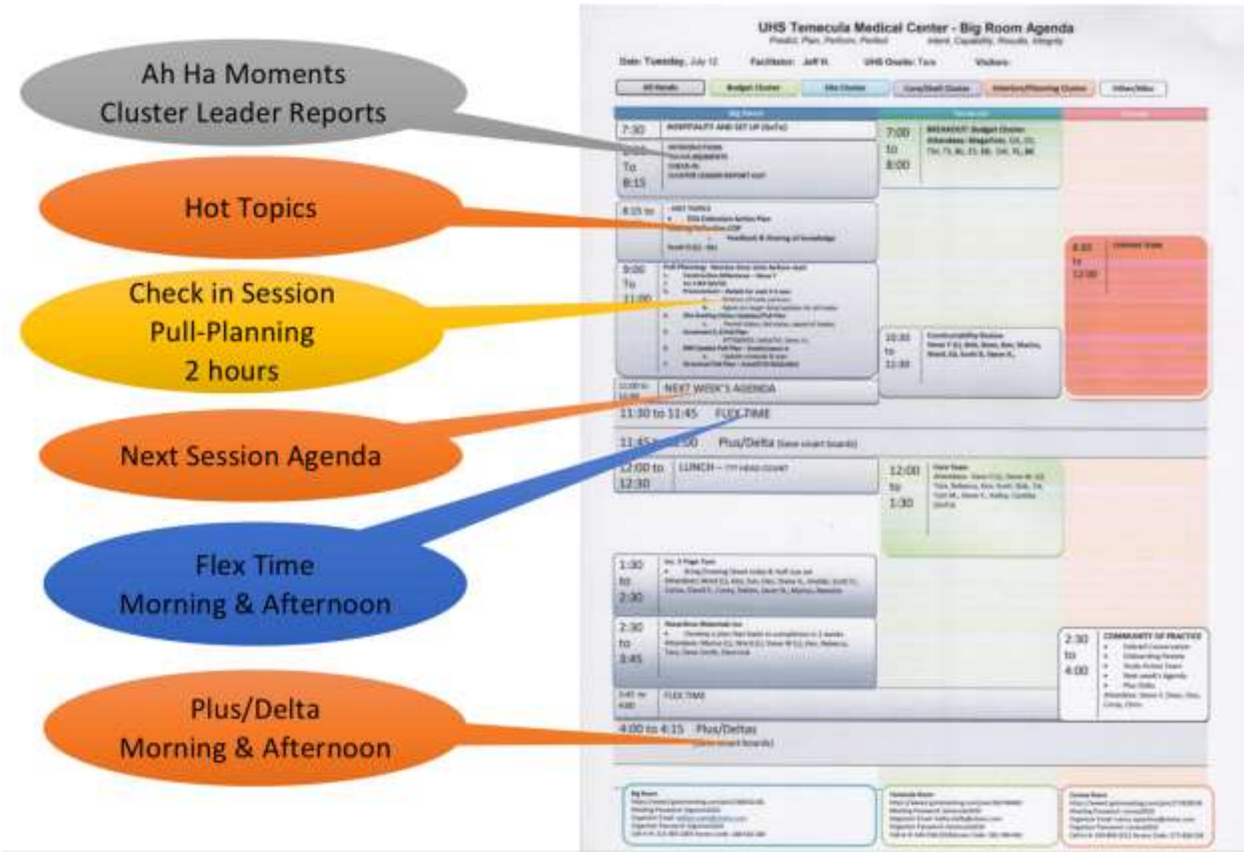


Figure 25: Big Room Meeting Agenda

In addition to the big room meetings, they also had daily check-in call (~15 minute) with the construction crew. It was created so that if a constraint came up, they can quickly remove them. The daily check-in call was well scripted so that people were not getting bogged down. At that meeting they would go through the following items:

1. **Report whether or not they were on track.**
2. **Identifying constraints**
3. **Determine who is the primary contributor to that constraint.**
4. **Gather commitments**
5. **Develop follow-up actions** – items that could be resolved within the cluster group were done within the group. Items that required cross-group problem solving were reported to the integrated team at the big room meetings.

According to the team, co-location, big room meetings, and the daily check-in calls led to:

- More accurate documents
- Early constructor inputs in the design
- Labor savings ideas incorporated into the design
- A higher rate of information flow (no RFIs)
- Better cost decisions and cost control
- Tighter tolerances

- Designing and installing the right sized systems
- More innovation

4.3.5 Collaborative Design Conversation

The team used a collaborative process where the designers took inputs from the trades and engineers to develop the design together (Figure 26). These collaborative design sessions included between 10 and 15 members in the same room. The designer(s) would propose several alternative design solutions and the rest team would give feedback, add information, and help evaluate the design. Using Smartboards, the information is documented electronically, which allows the team to revisit their work in the future.

Figure 26: Collaborative Design Conversation

Figure 27 shows a set of alternatives that were considered for the corridor design. The options include: (1) Double 40 Gen 2, (2) Double 40 Compact, (3) Double-Loaded 40, and (4) Traditional 40. Following the CBA methodology, objective data about the sets of alternatives were first collected and then the team decided between the alternatives based on the advantages each offered. The design decisions were locked in at the Last Responsible Moment, which is the point in time when failing to decide results in losing one or more of the options (Ballard and Howell, 2003). According to the architect (Mr. Wilson), the goal of set-based design is to lock in decisions at the appropriate time. Set-based design and the Last Planner allowed the team to select a building system and stick with it knowing that any changes after the Last Responsible Moment would lead to costly redesign and additional permitting problems with OSHPD. During the construction document stage, the design team was solely focused on detailing the design for shop fabrication and did not try to re-optimize the initial design.

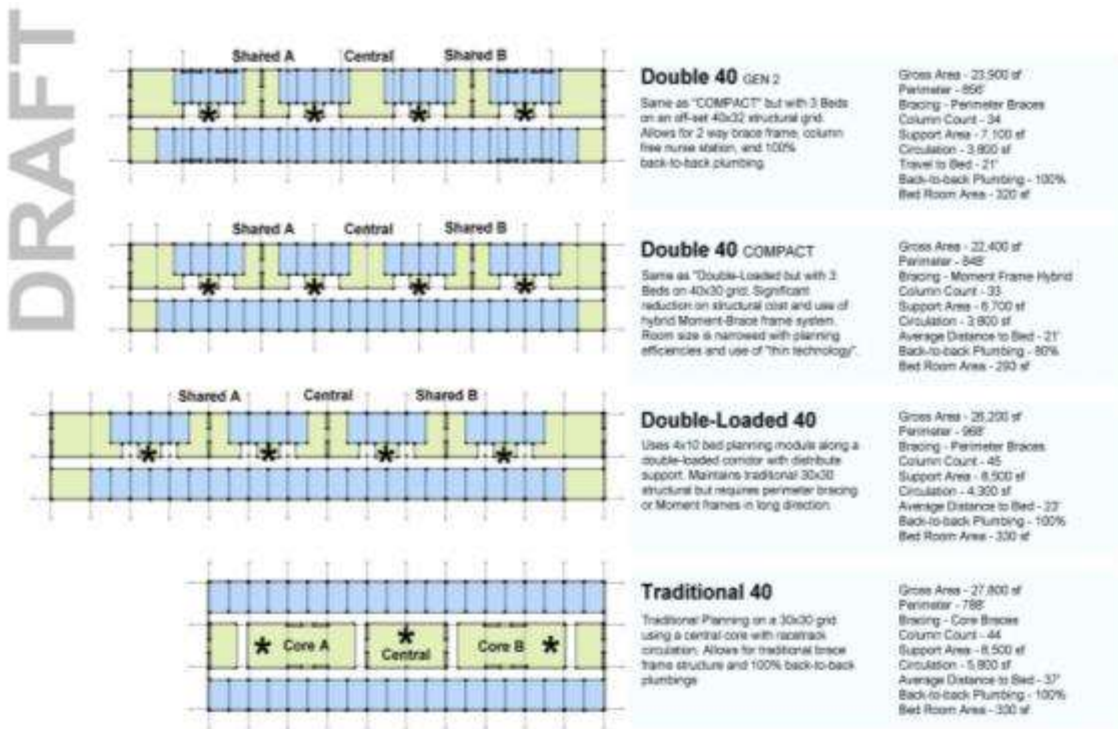


Figure 27: Sets of Corridor Design Alternatives

4.3.6 Simulation of Operations

After the development of the Target Cost and the initial target program, the architects met with the users to understand their needs. The goal is to make sure that there is an alignment between the initial program and the needs of the users. Once an alignment was established between the Target Cost, target program, and the needs of the users (Figure 28), the architect began the programming phase where they and a team of industrial engineers simulated the workflow and throughput based on the intended operations of the facilities. For example, the program may require a certain number of operating rooms and one of the tasks for the team is to simulate the average wait time, walking time, and overall capacity. The data from the simulation was used to inform the schematic design and detailed design.

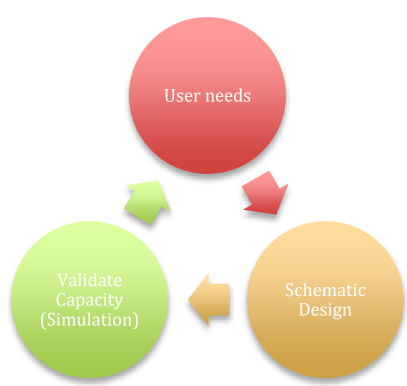


Figure 28: The Role of Simulation in TVD

Figure 29 through Figure 34 show an example of a simulation conducted on the Emergency Department. In this example, the design team used the initial floor layout to develop a value stream map of the intended service. They then translated the value stream map into a discrete event simulation. After inputting assumptions for the activity durations, arrival rates, batch sizes, etc. they were able to calculate the capacity of the Emergency Department, average wait time, and resource utilization. The simulation model for the Emergency Department allowed the team to validate whether or not the needs of the users can be met with the design. In some cases, the design team used the simulation to inform the development of design alternatives. They then used Choosing By Advantages to select the alternative that offered the greatest advantages while meeting the 'must-have' requirements. See appendix 6.2 for some examples of this process.

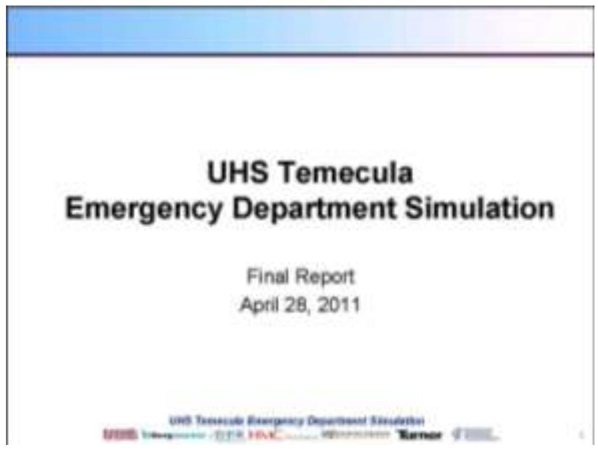


Figure 29: UHS Temecula ED Simulation

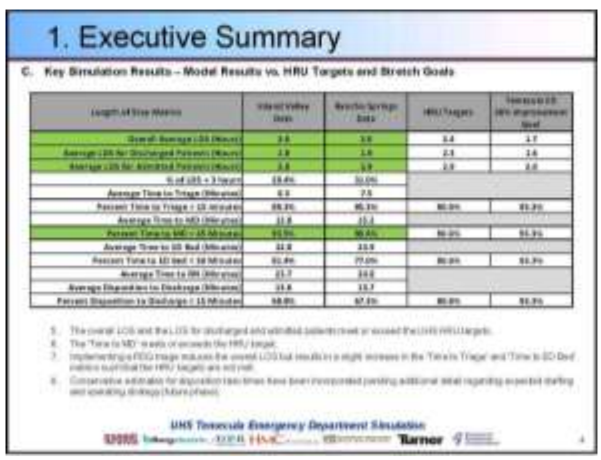


Figure 30: Executive Summary

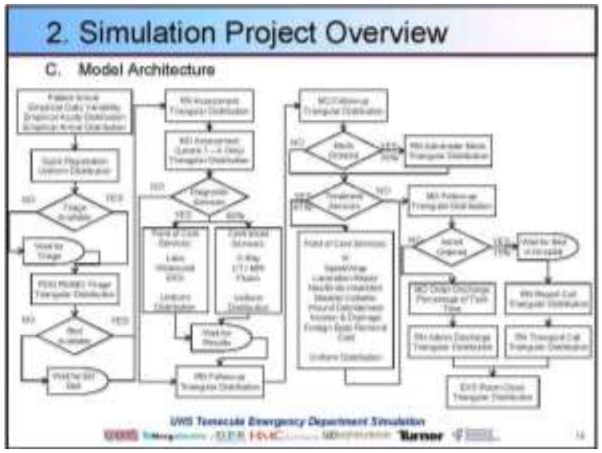


Figure 31: Simulation Overview

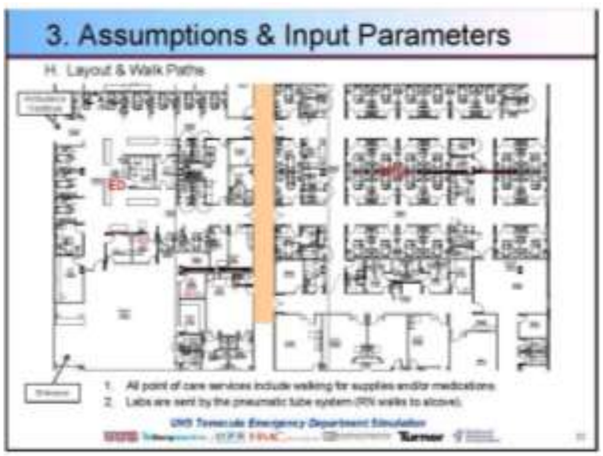


Figure 32: Assumptions and Input Parameters

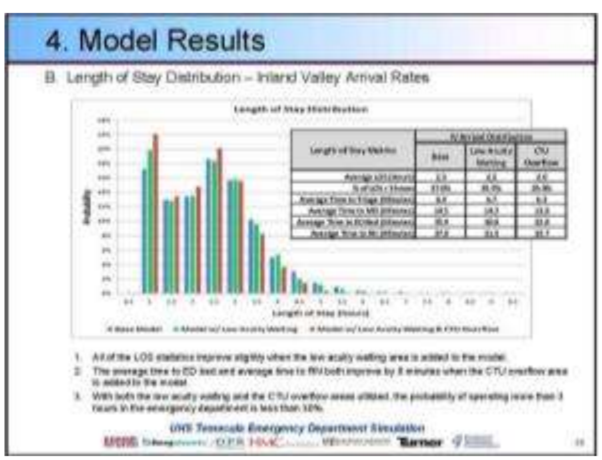


Figure 33: Simulation Model Results

Figure 34: Value Stream Mapping of Kitchen Operations

4.3.7 Building Information Modeling

The team started using BIM early in the schematic design phase. According to the team (see Lessons Learned Report) they on-boarded the BIM modelers too early in the design process.

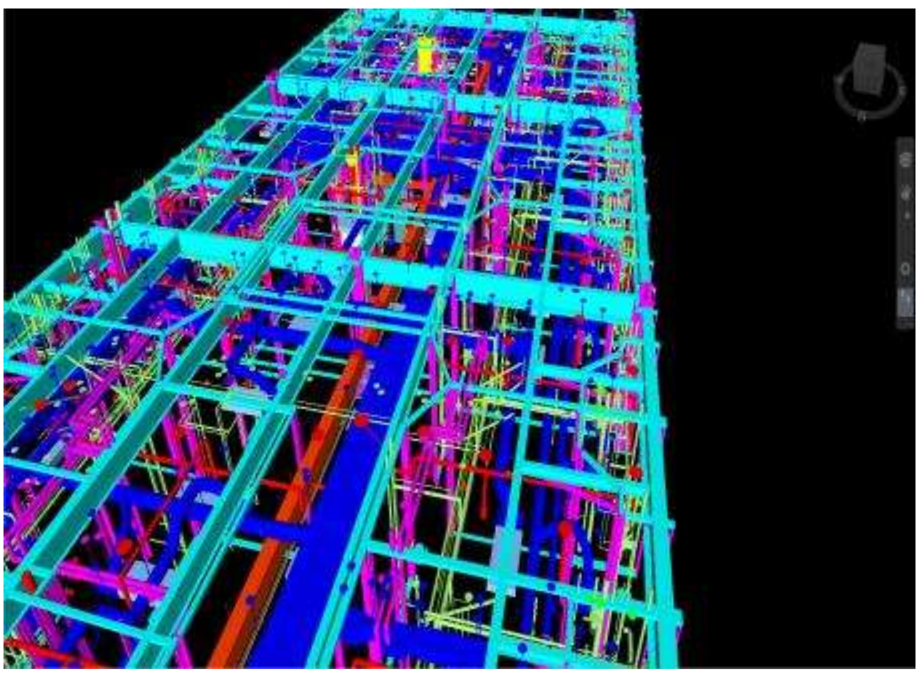


Figure 35: Temecula Valley BIM Model

The BIM coordination allowed the team to reap substantial savings because they could reduce their tolerance and prefabricate some of the construction off-site. The exterior wall and the roof trusses were prefabricated in major panels and erected on-site. The team went as far as brainstorming ideas to prefabricate bathrooms off-site, which ultimately did not happen.

Figure 36: Prefabricated Exterior Walls

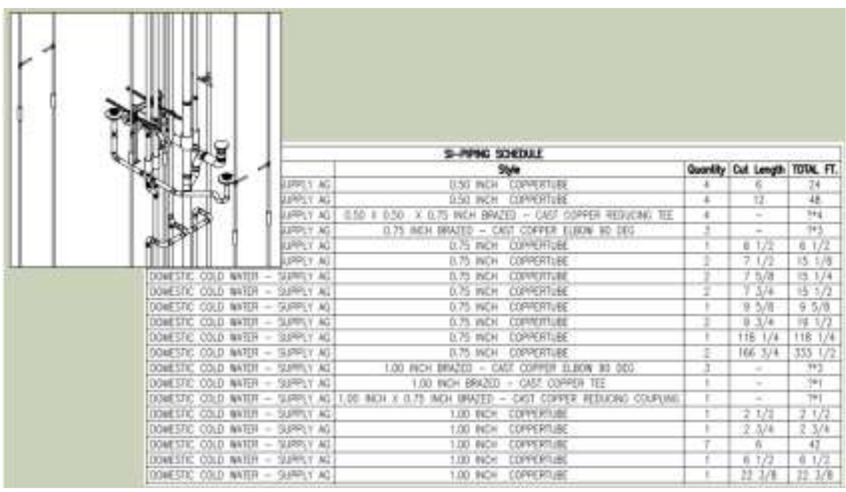
Figure 37: Prefabricated Roof Truss

At the time of the Temecula Valley project in 2010, BIM technology was not advanced enough for the team to use a single model. The team used mainly Autodesk 3-D for model coordination and exported the model dimensions into specific software packages for CNC and shop fabrications. The team did not use Revit because it did not have the information and data compatibility capabilities that it currently has. The team only used BIM for model-based quantity takeoffs on a select number of scope (ducts, piping, and framing; Figure 38; Figure 39). In the design phase, the cost estimates were forecasted based on the alternatives in the set-based design process using on-screen takeoffs. Future projects may look at using

BIM for automatic quantity takeoffs to aid in the TVD process. During the construction phase, the cost estimates were forecasted based on labor productivity rates, general conditions, and market prices of materials that had not yet been bought out.

The TVD/IPD provided more transparency in the BIM process. The team found that:

- "We (and the industry) are over-modeling"
- The BIM process is approximately 30% to 40% too costly
- BIM Leadership is young and inexperience
- Models are created for differing purposes
- The main trades that can benefit from BIM are the ducts, piping, and framing.
- BIM works best when the key players are co-located
- BIM requires a process plan
    - Understand the needs/uses
    - Understand the dependencies
    - Understand what is generating cost
    - Modularize the model
- Mechanical, plumbing, and framing needs to share leadership for BIM coordination
- BIM can make costs more predictable



SI-PIPING SCHEDULE				
	Style	Quantity	Cut Length	TOTAL FT.
SUPPLY AG	0.50 INCH COPPERTUBE	4	6	24
SUPPLY AG	0.50 INCH COPPERTUBE	4	12	48
SUPPLY AG	0.50 X 0.50 X 0.75 INCH BRAZED - CAST COPPER REDUCING TEE	4	-	?*4
SUPPLY AG	0.75 INCH BRAZED - CAST COPPER ELBOW 90 DEG	3	-	?*3
SUPPLY AG	0.75 INCH COPPERTUBE	1	6 1/2	6 1/2
SUPPLY AG	0.75 INCH COPPERTUBE	2	7 1/2	15 1/8
DOMESTIC COLD WATER - SUPPLY AG	0.75 INCH COPPERTUBE	2	7 5/8	15 1/4
DOMESTIC COLD WATER - SUPPLY AG	0.75 INCH COPPERTUBE	2	7 3/4	15 1/2
DOMESTIC COLD WATER - SUPPLY AG	0.75 INCH COPPERTUBE	1	9 5/8	9 5/8
DOMESTIC COLD WATER - SUPPLY AG	0.75 INCH COPPERTUBE	2	9 3/4	19 1/2
DOMESTIC COLD WATER - SUPPLY AG	0.75 INCH COPPERTUBE	1	118 1/4	118 1/4
DOMESTIC COLD WATER - SUPPLY AG	0.75 INCH COPPERTUBE	2	166 3/4	333 1/2
DOMESTIC COLD WATER - SUPPLY AG	1.00 INCH BRAZED - CAST COPPER ELBOW 90 DEG	3	-	?*3
DOMESTIC COLD WATER - SUPPLY AG	1.00 INCH BRAZED - CAST COPPER TEE	1	-	?*1
DOMESTIC COLD WATER - SUPPLY AG	1.00 INCH X 0.75 INCH BRAZED - CAST COPPER REDUCING COUPLING	1	-	?*1
DOMESTIC COLD WATER - SUPPLY AG	1.00 INCH COPPERTUBE	1	2 1/2	2 1/2
DOMESTIC COLD WATER - SUPPLY AG	1.00 INCH COPPERTUBE	1	2 3/4	2 3/4
DOMESTIC COLD WATER - SUPPLY AG	1.00 INCH COPPERTUBE	7	6	42
DOMESTIC COLD WATER - SUPPLY AG	1.00 INCH COPPERTUBE	1	6 1/2	6 1/2
DOMESTIC COLD WATER - SUPPLY AG	1.00 INCH COPPERTUBE	1	22 3/8	22 3/8

Figure 38: BIM for Piping Coordination and Quantity Take-offs

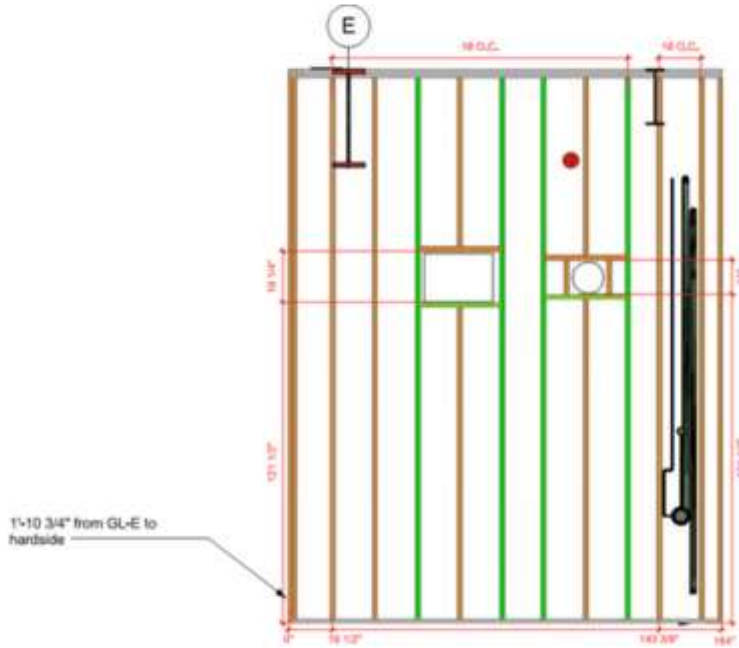


Figure 39: Framing Layout and Spool Sheets from BIM Model

4.3.8 Last Planner® System of Production Control For Design

The team used the Last Planner® in both the design and construction phase. The collaborative pull scheduling and commitment planning of the Last Planner® was brainstormed with sticky notes and then recorded and tracked using OurPlan™ (Figure 40; Figure 55; Figure 56). The Last Planner® System of Production Control breaks the project schedule into: a master schedule, phase schedules, lookahead schedules, and weekly work plans (Ballard, 2000). The schedule is developed in greater detail as it approaches the work. The Percent Plan Complete (PPC) measures the percentage of work that was completed vs. the amount of work that was planned for a particular day. This metric encourages reflection and learning from breakdowns (Ballard, 2000). On the Temecula Valley project, the PPC clustered around 80% (Figure 57). The team revised their master schedule every 3 weeks, their phase schedule every week, and their weekly work plan on a daily basis.

Figure 40: Pull Planning Session

4.3.9 Set-Based Design

The process during schematic design and design development followed the progression of developing: (1) the systems, (2) the assembly, (3) subsystems, (4) components, and (5) the details and finishes. The team used Set-Based Design, also known as Set-Based Concurrent Engineering, which was originally developed by Toyota (Sobek et al., 1999). Under the Set-Based Design approach, the team generates alternatives and chooses between them at the “last responsible moment” (Parrish, 2009; Figure 41). An acceptable alternative is developed early in the design process as insurance against ‘the first irresponsible moment’; i.e., extending the project schedule. The alternatives are reviewed by a cross-disciplinary team using Choosing by Advantages to ensure that stakeholder values are met (Arroyo, 2014).

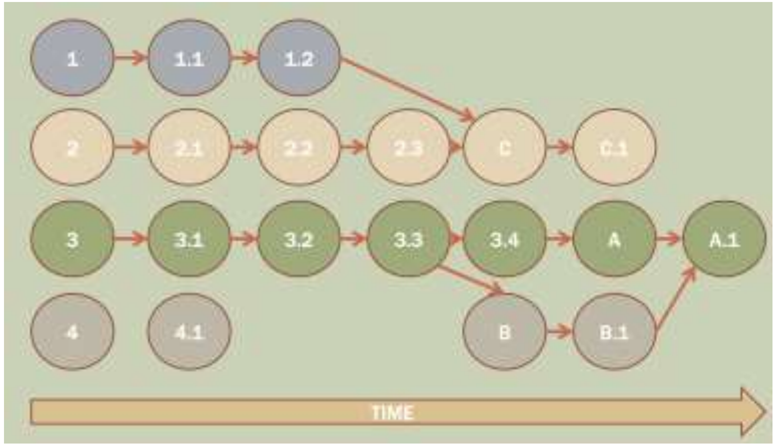


Figure 41: Set-Based Design

4.3.10 A3 Reports

The design team documented all major design alternatives using A3s (Figure 42). The A3 document is a single sheet of paper that was used at Toyota to in a systematic problem solving process (Shook, 2009). At Temecula Valley, the A3 document included sections for: (1) The issue, (2) Background, (3) Current condition / problem analysis, (4) Target condition, (5) Analysis, (6) Proposed countermeasures, and (7) Follow-up. Figures 42 and 43 show two examples of A3s that were used to document design alternatives. Within the A3s, the advantages of each of the alternatives are listed and used to aid the decision-making process. The team used A3s to document all major decisions including: (1) building system selection, (2) selection of team members, (3) component selections, and (4) material selections. New members who joined the project could look through a binder of A3s to quickly get up to speed on the major decisions and understand the history of the project. Likewise, the A3s documentation process reduced the loss of institutional knowledge when an individual left the project.

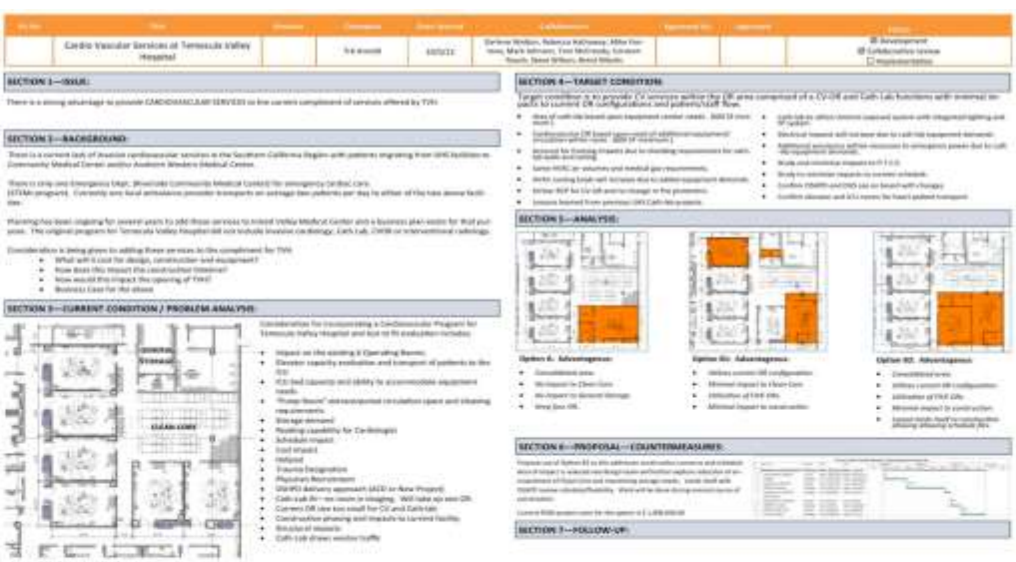


Figure 42: Temecula Valley A3 (Cardio Vascular Services)

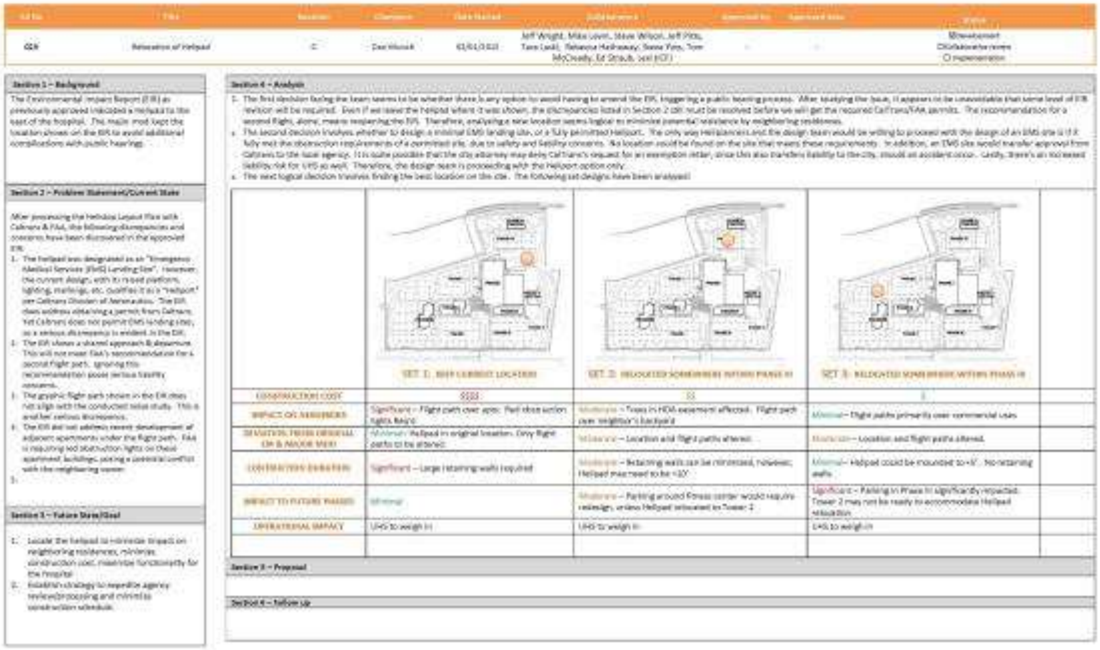


Figure 43:Temecula Valley A3 (Location of Hospital)

The Temecula team also documented all of their monthly updates using A3s. The A3s includes the key performance metrics (e.g., budget, schedule, safety) and lessons learned (Figure 44).

Figure 44: December 2012 Report

4.3.11 Value Engineering

Dell'Isola (1982) states, "the optimum time to conduct a value review is after the preliminary submittal stage and before working drawings are started"; however, most construction projects perform VE after a substantial portion of the design has already been completed. Due to the reactive nature of VE and the use of the practice to cut costs (often with compromises to scope and quality), the term VE has a bad connotation in the construction industry.

One owner representative on Temecula Valley said: "We had a very specific business model. We do not need the fancy glamorous hotel, we just needed a facility that was fit for our needs." The process of evaluating the design based on its functional value and optimizing it to fit the user's need is a core practice of TVD. The participants on Temecula Valley reported in our interviews that they did not use "Value Engineering". While true that they did not do VE after design was nominally complete, but needed to be brought into budget, the basic concept of value engineering was used, but proactively in generating the design, not after-the-fact. Their practice of 'VE' followed the disciplined approach of Set-based Design and relied on Choosing By Advantages and A3 reports for decision-making and documentation (Appendix 6.2).

4.3.12 Cost Modeling and Cost Tracking

The project team used a centralized spreadsheet to track all of their costs, uncertainties (risk and opportunity), and monthly billables. As the project progressed, cost items gradually became locked into place through the Set-based Design process. At the Last Responsible Moment, certain decisions were made and the cost associated with them became fixed. Decisions not yet made were assigned "rough order of magnitude" (ROM) estimates. The current cost estimate shown in Figure 45 is the sum of the cost that has been fixed and the remaining ROM items.

At any point in time, there were cost items that were locked in place because the design had already been committed or the work was already finished. Any attempts at changing the cost items that were already locked in would result in greater cost due to negative iterations, rework, and delays. The remainder of the cost items is still malleable. The malleable cost items have associated uncertainties with them that reflect either a risk or an opportunity. The TVD/IPD team tracked these cost items very carefully and set targets to reduce waste in the remaining work (Figure 45). These targets created a pathway for the team to realize their full profits at the end of the project. Figure 45 shows the cost spreadsheet on February 2012. At this time in the project, the team needs to reduce $2.5 million from the project cost in order to realize 100% of their negotiated profits. The TVD/IPD had $84.2 million that has not yet been spent.

Temecula Valley Hospital
Budget & Billing Update

February 29, 2012

A	B	C	D	E	F	G	H	I	J	K
Team Member	PTCE Budget	PTCE Budget	Feb-12 Budget	Monthly Delta	Transfer To:	Transfer From:	Description	Feb-12 Billing	Total Billing	% Complete
Joint Venture (JV)	54,874,842	54,874,842	54,841,765	187,123				0	12,628,437	23%
				60,500		MP	OR Ceilings			
				-1,551,298	DC		Transfer Fee scenario (TGO adjustment) to Commodity line items			
				[illegible]		CC	[illegible]			
				0	Unassigned					
Mechanical & Plumbing (MP)	24,615,454	24,615,454	24,396,259	-219,195				0	4,351,194	18%
				-60,500	JV		OR Ceilings			
				35,000		DC	Add storm drains at perimeter			
				-23,800	CC		Underground productivity adjustment			
				0	Unassigned					
Electrical (E)	13,751,700	13,751,700	14,448,634	696,934				0	3,045,964	21%
				-32,970	JV		OR Ceilings			
				22,259		DC	New Pedestal for De Portola			
				-504,940	CC		Estimate Update			
				0	Unassigned					
Drywall & Framing (DF)	8,035,966	8,035,966	8,353,949	317,983					724,821	8%
				47,000		JV	[illegible]			
				79,342		DC	[illegible]			
				-8,294	CC		[illegible]			
				0	Unassigned					
Fire Protection (FP)	1,231,721	1,231,721	1,289,707	57,986					295,243	23%
				-10,270	MP		Fireproofing			
				84,285		DC	Additional BR and coordination costs			
				-8,170	CC		Fireproofing/budget versus cost			
				0	Unassigned					
Architecture (AR)	7,744,830	7,744,830	7,496,485	-248,345					5,766,041	77%
				-22,000	JV		Traffic consultant			
				-200,000	DC		[illegible]			
				[illegible]		CC	[illegible]			
				0	Unassigned					
Owner Risk Items (UHS)	9,094,068	9,094,068	9,862,965	768,897						
				-26,000	JV		Additional inspection costs			
				50,000		DC	[illegible]			
				0	Unassigned					
Owner Non-Risk Items (UHS)	24,661,552	24,661,552	24,661,552	0						
Design Contingency (DC)	1,500,000	1,500,000	851,500	-648,500						
				[illegible]	JV		[illegible]			
Construction Contingency (CC)	2,850,516	2,850,516	2,150,141	-700,375						
				[illegible]	JV		[illegible]			
Profit (P)	1,883,551	1,883,551	1,489,043	-394,508						
Total	150,044,000	150,044,000	150,044,000							

Figure 45: Budget and Billing Tracking

The Path Back		
We must work towards **2,541,047** in Project Savings, in order to recognize 100% of our planned Project Profit.		
Here's how we get there...		
Item	**Value**	**Date**
JV Escalation Contingency Reduction	325,000	02/01/12
JV Buy out of commodity trades	300,000	04/01/12
MP to target 3.5% general conditions personnel cost reduction	77,913	04/01/12
MP to reduce copper costs by 4%	50,000	05/01/12
MP to reduce major subcontracts by 3%	32,989	05/01/12
MP to target 4% plumbing field labor productivity gains	167,887	08/01/12
DF to target $98,000 in drywall labor productivity gains	98,000	08/01/12
DF to target $89,000 in framing productivity gains	89,000	08/01/12
A to target $75,000 reduction in reimbursable costs	75,000	08/01/12
E to target 5% in material buyouts	150,000	09/01/12
E to target 4% general conditions cost reduction	45,000	09/01/12
E to target 3.5% in commodity material cost savings	65,000	09/01/12
JV Productivity and Innovation	250,000	09/01/12
JV Savings in Cost to Complete	570,556	01/01/13
E to target 6% in labor productivity gains	71,000	03/01/13
Subtotal	2,367,345	
Additional Reduction in **DC** and/or **CC** required	173,702	
Total	**2,541,047**	
Total Project Contingencies held are	**3,164,133**	
Total Project Contingencies can cover Project Profit Shortfall		

Savings Required Prorated for Each Team Member	Left to Spend	Target Savings	Target Savings as %
Joint Venture (JV)	42,213,328	1,273,715	
Mechanical & Plumbing (MP)	20,045,065	604,826	
Electrical (E)	11,402,670	344,056	
Drywall & Framing (DF)	7,829,128	236,231	
Fire Protection (FP)	994,464	30,006	
Architecture (AR)	1,730,444	52,213	
Total	**84,215,099**	**2,541,047**	**3.02%**

Figure 46: Cost Tracking

4.3.13 Risk Identification and Risk Management

The team tracked all potential known risks and opportunities on an Excel marker log. They then assigned a rough order of magnitude (ROM) estimate to each risk or opportunity's potential impact on the project. The shared pains and gains meant that the team had to trust each other. Within in this trust; however, is also the permission to challenge and question other members of the team. Since everyone's best interest is aligned with the interest of the project, the challenges are not construed as personal or professional doubt but rather as a way to ensure that the actions taken are best for the project.

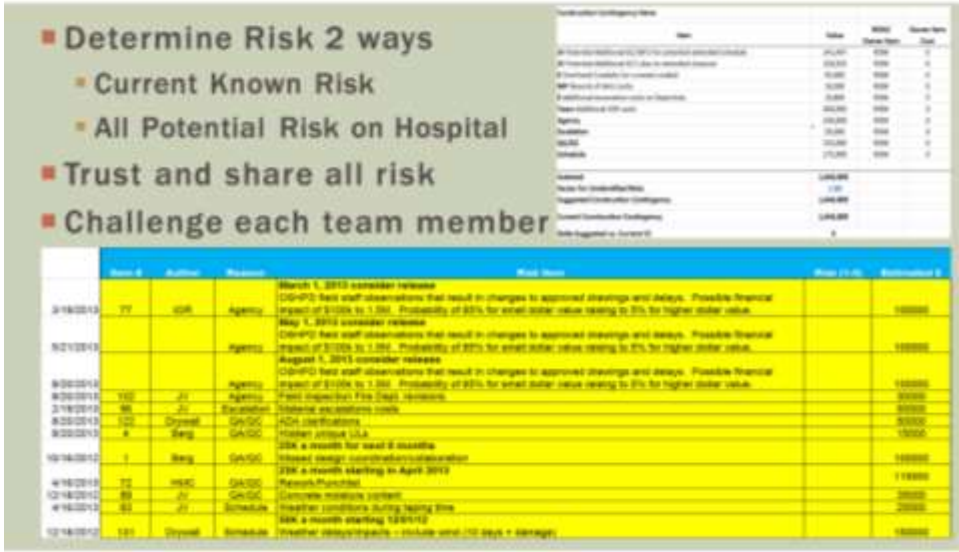


Figure 47: Risk Identification and Risk Management

4.3.14 Moving Money Between Boundaries

Figure 48: Expected Cost Throughout the Project

In order to drive the design to the Target Cost, the team kept track of:

(1) At-risk cost of work
(2) Not at-risk cost of work
(3) Contingency
(4) Realized savings
(5) Risk items
(6) Anticipated savings that have not yet been realized
(7) Realized profit
(8) Anticipated profit on remaining work, and (8) the design team's burn down rate.

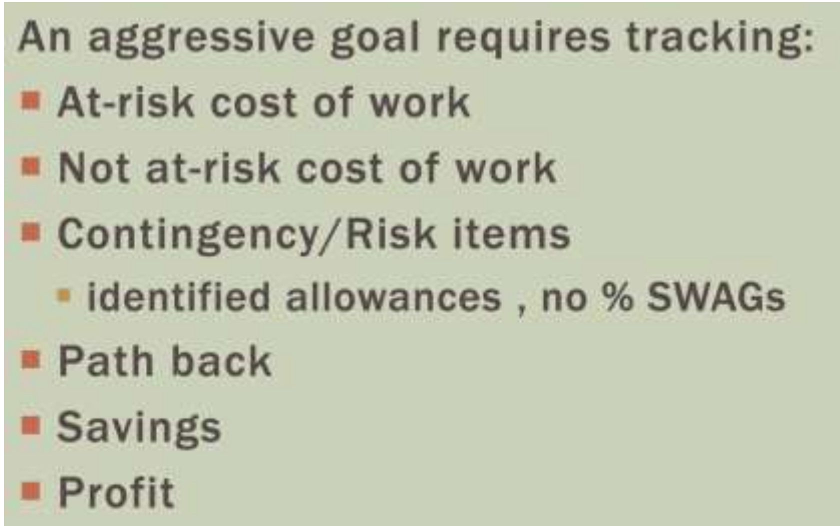


Figure 49: Cost Tracking

As a way to realize their full profits, the team kept track of cost saving opportunities (Figure 50). They placed all of their opportunities inside an Excel sheet that they called "The Path Back". In the figure below, the team needs to achieve $2,935,744 in savings in order to recognize 100% of the planned profit.

The Path Back				
We must work towards **(2,835,744)** in Project Savings, in order to recognize 100% of our planned Project Profit.				
Here's how we get there...				
Item	**Value**	**Date**	**Comment**	
JV Escalation Contingency Reduction	0	Done	Escalation will be managed on the "Risk" tab	
JV Buy out of commodity trades	0	Done	$118,800 recognized in the April Budget	118,800
MP to target 3.5% general conditions personnel cost reduction	0	Done	Recognized $150,000 in savings on 3/30	150,000
JV Buy out of commodity trades	0	Done	$181,200 recognized in the May Budget	181,200
MP to reduce copper costs by 4%	0	Done	Recognized $50,000 in savings on 6/19/12 budget meeting	50,000
JV Savings on Inc 2 and 3 (Anderson Settlement Savings)	0	Done	Recognized $29,893 in savings on 6/19/12 budget meeting	29,893
JV Remove all Davits shown on drawings entirely	0	Done	Recognized $13,000 in savings on 6/19/12 budget meeting	13,000
Team Betterment of schedule due to slurry	0	Done	Recognized $200,000 in savings on construction contingency risk on 6/19/12 bu	200,000
JV Savings in Cost to Complete (Steel, Rebar, Site Utilities)	0	Done	Recognized $150,000 in savings on 7/17/12 budget meeting	150,000
DF to target $17,325 in framing productivity gains	0	Done	Recognized $17,325 in savings on 7/17/12 budget meeting	17,325
MP Rad Farm Deduct	0	Done	Recognized $18,000 in savings on 8/21/2012 budget meeting	18,000
MP Field Riser Productivity Gains (Mechanical Piping)	0	Done	Recognized $15,000 in savings on 8/21/2012 budget meeting	15,000
MP Hanger Shop Prefab Productivity Gains	0	Done	Recognized $39,000 in savings on 8/21/2012 budget meeting	39,000
MP Plumbing Cast Iron Productivity Gains	0	Done	Recognized $100,000 in savings on 8/21/2012 budget meeting	100,000
MP Hanger Field Productivity Gains	0	Done	Recognized $30,000 in savings on 8/21/2012 budget meeting	30,000
JV Savings in Cost to complete (Earthwork, Rebar, Steel, Fencing)	0	Done	Recognized $150,000 in savings on 8/21/2012 budget meeting	150,000
JV Incentive Plan for Commodity Trades (Doors and Flooring)	0	Done	Recognized $20,000 in savings on 8/21/2012 budget meeting	20,000
A to target $22,500 reduction in reimbursable costs	0	Done	Recognized $22,500 in savings on 9/25/2012 budget meeting	22,500
MP Savings in Roof Duct	0	Done	Recognized $40,000 in savings on 9/25/2012 budget meeting	40,000
MP Shop Propress overhead productivity Savings	0	Done	Recognized $10,000 in savings on 9/25/2012 budget meeting	10,000
E to target 5% in material buyouts	0	Done	Recognized $80,000 in savings on 9/25/2012 budget meeting	80,000

Figure 50: The Path Back

For the work at risk, the team developed the following categories to track the finances: (1) Joint-venture, (2) Mechanical and Plumbing, (3) Electrical, (4) Drywall and Framing, (5) Fire Protection, (7) Owner's scope at risk, (8) Design Contingency, and (9) Construction Contingency. Every month, the team reviews their current monthly budget report and compares it with the previous month's budget report (Figure 51). They documented risk and opportunity items that were realized in that month and the associated change in the cost that resulted from them. The total monthly change in cost is documented as the "Month Delta". All items listed on the budget report include: (1) the dollar impact, (2) the parties involved, and (3) a short description. To facilitate the movement of money between organizational and cluster boundaries, each transaction also includes a documentation of the parties that the funds are being transferred from and to.

Budget & Billing Update							
A	B	C	D	E	F	G	H
Team Member	PTCE Budget	Feb-12 Budget	Mar-12 Budget	Monthly Delta	Transfer To:	Transfer From:	Description
Joint Venture (JV)	54,674,642	54,841,765	55,204,368	362,603			
				11,546		UHS	Gas Company fee
				1,000		DC	Support Steel for Standpipe
				30,000		DC	Increase in Increment 3 costs
				25,000		DC	Redesign of Storm drain line W15 due to depth
				25,000		DC	ACD # 2 Extend Ambulance Canopy
				10,000		DC	ACD # 4 Expand Area of O2 tank and increase wall enclosure height
				28,406		DC	Replace fiber line from Margarita to Pechanga Parkway
				25,000		DC	Revised Deportola Profiles (URS miss)
				10,000		DC	Slab depressions in kitchen slab
				5,000		DC	Added Hairpins and Ties per Louis Choi RFI # 5081
				150,000		DC	Approved Landscape Drawings
				-381	DC		Reduction in Approved offsite plans RCWD, EMWD, SIP
				42,032		CC	Increase in ESA Direct Cost Impact
				0	Unassigned		
Mechanical & Plumbing (MP)	24,615,454	24,396,259	24,428,656	32,397			
				4,635		FP	Spanner brackets provided to FP
				4,262		FP	Blue hangers provided to FP
				7,500		DC	Added toilet on 4th Floor
				7,500		DC	New housekeeping closet
				8,500		DC	Added drinking fountain in waiting room
				150,000		DC	Additional BIM Costs

Figure 51: Budget and Billing Update

The team documented all owner-initiated items in a spreadsheet. For each item they recorded: (1) a description, (2) the members involved, (3) the dollar impact, (4) the driver of the scope change, (5) the reason for the scope change, (6) whether or not the scope was added on a "whim", and (7) whether the change was foreseeable. Using this process, they were able to track changes to the scope and determine who is financially responsible for the change -- the IPD/TVD team or the owner.

What specific scope drove the change in cost?	Why did the scope change?	Did we challenge the scope change in person? With who?	What was our basis for challenging the scope?	Was the decision to add the scope a "whim"	Should we have known?
Change in mat'l and labor. Increased sewer line from 8" to 10". Changes in grade after site was already graded.	In order to capture the future sewer stubouts for the fitness center due to its location on site the sewer was increased in size in order for proper flow throughout campus.	No. Site unforeseen.	NA	NA	No. Unforeseen conditions.
Change in mat'l and labor. Shifted a roadway and ug utilities.	URS did not analyze the flood plain correctly. Under calculated the flood plain and utilized an out of date drawing.	Yes. Challenged with Excel and they indicated that it was designed wrong.	We had an approved drawing from the city.	No.	Yes. URS should have understood the flood plain calculations.
Staff assigned to the project unable to proceed with the construction of the building	*The reviewing agency did not have the staff to expedite the approval of the Enviromentally sensitive area*	*The team offered to pay for an independent reviewer however this was not acceptable to water district. The team also offered to pay for the in house reviewer's overtime costs and this was also shot down.*	*The review period was specified to be 90 days and it exceeded this amount.*	*No this was due to lack of staff.*	*We could not have expected to know that the review time would take so long.*
		The team offered to pay for an independent reviewer however this was not acceptable to water district. The team also offered to pay for the in			*We could not have*

Figure 52: Changes in Scope Initiated by the Owner

4.3.15 Challenges During Design

After starting the project, the team faced many challenges that increased the estimated cost (Figure 53). Some these problems arose from legacy designs that the team had inherited from the architect that left the joint venture. As they looked at the design further, they discovered items that were not included in their estimates or were not finished in design (e.g., extra 12 in width in patient rooms). The preconstruction manager from the Joint Venture commented: "The increases in cost during the design phase is very common when detailing from an initial schematic design. These are often expected on most projects." In total the challenges increased the total project cost from $144 MM to $156.6 MM. The $162 MM number shown in figure 11 also includes the owner's IT/IS budget. Some of the cost increases during design (Figure 53) would typically be taken from an owner's contingency. On this project, the allowable cost was all that the owner could spend for this project and there all cost increases, regardless of its origins, are part of the project's cost.

Challenges Found After $144MM Target Value Set	
Bad Soils and Deep Foundations	$952,000
City Conditions of Approval	$2,170,000
Convert "B" to "I" Occupancy	$1,200,000
Cost to Grade Entire Site	$330,000
Elevator Utilities For Future Growth	$50,000
Extra 12 in. Width in Patient Room	$605,000
IT/IS Systems Budget	$6,000,000
Site on Flood Plain	$665,000
Utility Re-Route for Well/Culvert	$200,000
Water Management	$470,000
Total Challenges	$12,642,000

Figure 53: Challenges That Increased Cost

4.3.16 Innovations During Design

The Target Value Design process started in Q4 2010 and lasted until the start of construction in Q3 2011. During this time, the team was able to develop innovations that resulted in a $16 MM savings. Figure 54 shows $13.3 MM as the anticipated savings from the TVD process. During the schematic design phase, the superintendents from the general contractors took an active role in planning the construction sequence with the architects and engineers who were designing the project. The effort to include the superintendents in the early design phase allowed the team to make improvements to the construction schedule and saved 6 months from their initial schedule. The 6 months reduction in the schedule resulted in approximately $2.25 million in savings from the general conditions alone with much greater benefits for the client in terms of being able to open the hospital early. As a result of the innovations and the reduction in the project's schedule, the team was able to save ~ $16 MM during design. According to the owner, team saved an additional $7 million during the construction phase due to improved labor productivity as a result of applying Lean in the field.

Innovations With Cost Saving Impact	
HVAC Decentralized System	$3,000,000
Hybrid Structural Framing	$1,300,000
Improve Exterior Wall Efficiency	$500,000
Increased Construction Productivity	$500,000
Interior Finish Target Value Design	$1,000,000
Optimize Gross Square Footage	$3,000,000
Redesign Rooftop Enhancements	$1,200,000
Reduce CAV Design Quantity	$400,000
Re-evaluate Geotech Data	$1,178,000
Simplify Storm Drainage System	$725,000
Additional Target Value Design	$568,000
Total Innovations	$13,371,000

Figure 54: Target Value Design Innovations

4.4 Steering to Targets During Construction

4.4.1 Last Planner for Construction

The team used the Last Planner to coordinate the work of the trades during construction. The weekly planning meetings included the representatives of the key trades (i.e., superintendents and foremans), project manager, and architect. The goal of the Last Planner is to increase the reliability of the workflow and the hand-offs between the trades. The team developed and updated their Last Planner schedule on the wall with stickie notes. At the end of their planning session, a project engineer would enter the data into the OurPlan software. The team used OurPlan to track and visual the commitments and production schedule.

Figure 55: Weekly Planning Meeting

Figure 56: OurPlan

In addition to tracking the Percent Plan Completed (PPC), the Temecula Valley team also kept track of the Task Made Ready (TMR) and Task Anticipated (TA). “TA measures the percentage of tasks anticipated on the lookahead plan two weeks ahead of execution. TMR measures the performance of lookahead planning in identifying and removing constraints to make tasks ready for execution” (Hamzeh et al., 2012).

To measure the covariance of the variables for TMR and TA relative to PPC, we use a statistical tool known as the Pearson Coefficient. The Pearson Coefficient of the PPC and Task Made Ready (TMR) is .79; this suggests that there is a strong correlation between the percent of TMR and PPC. The Pearson Coefficient of the PPC and the Task Anticipated is .2; this suggests that there is a weak correlation between the percentage of TA and PPC. Hamzeh et al. (2012) hypothesized that: "improving the performance of lookahead planning (i.e., increasing TA and TMR) results in improving the reliability of weekly work plans (i.e., increasing PPC)". More data are needed to independently verify these findings. Additionally, a theory is required to explain why there is a strong correlation between PPC and TMR and a weak correlation between PPC and TA.

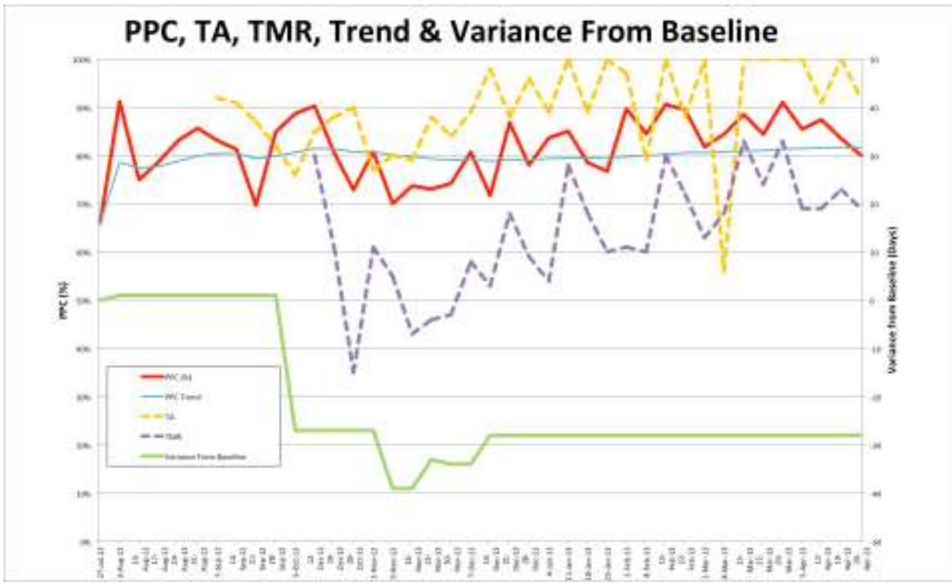


Figure 57: Percent Plan Completed

4.4.2 Location Based Planning

For the production planning, the team used a line of balance software from Vico called Flowline (Figure 48). To use the Flowline software, the team first divided the building into 4 different zones (a, b, c, d) for each floor. On the vertical axis of the Flowline software is space (floor and zone). On the horizontal axis is the timeline of the project from the beginning to the end of construction. The goal of the line of balance (also known as location-based planning) is to ensure that only one trade is working in an area at one time and thus avoid the problem of trade stacking. The line of balance tracks two things: (1) when a particular trade should be working in a particular area and (2) the anticipated production rate of each trade assuming a certain crew size. First is shown by when the trade's color line crosses the box that is surrounded by a space and time intersection. The slope of the trade's line shows the later. The slope is a visual representation of production rate ($\Delta Y / \Delta X = \Delta Zone / \Delta Time$). For example, if a trade can complete zones A and Zones B in 1 week their production rate would be 2 zones per week.

The location-based plan supported and was used with the Last Planner to improve the reliability of workflow and PPC. The Last Planner uses reliable commitments, a lookahead schedule, constraint removal, and learning from breakdowns to improve PPC over time. The Last Planner does not explicitly tie the production with the layout of the building and as result commitments may be made which are not physically possible with trade stacking. The location-based schedule uses the physics of the building to further support the objectives of the Last Planner.

The location-based planning was developed by the superintendents who had the most knowledge on construction techniques and anticipated labor productivity rates. The superintendents helped developed the Flowline schedule during the design development and their involvement helped the team shorten the schedule by 6 months. The interviewees reported that for the trades working in the field, the Flowline schedule was much more intuitive to visualize their work than Gantt charts.

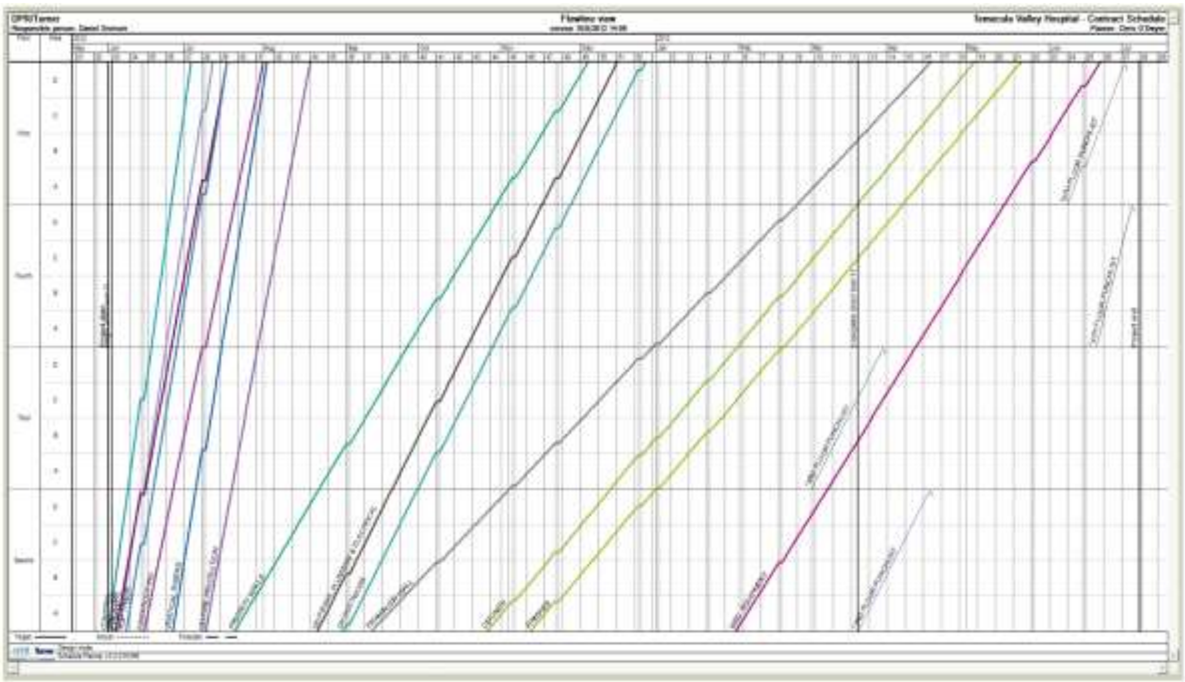


Figure 58:Flowline for Location-based Planning

4.4.3 Value Stream Mapping

One of the reasons why the Temecula Valley project was able to hit its aggressive cost and schedule targets was their practice of bringing Lean to the field crew. The TVD/IPD team encouraged their crews to practice 5S and conduct Value Stream Mapping studies. The people who were “doing the work” took video recording, analyzed the videos, identified waste, and developed ideas to make the process more efficient. In total, the TVH team conducted over 150 value streams and video recording studies. The team extended Lean training beyond just the members in the risk pool. One such example is the door installation trade, which was a Lump Sum subcontractor (Figure 61). Using Value Stream Mapping, the door installation trade was able to reduce waste and improve their profitability.

Figure 59: Video Recording of Work

Figure 60: Value Stream Map of Door Installations

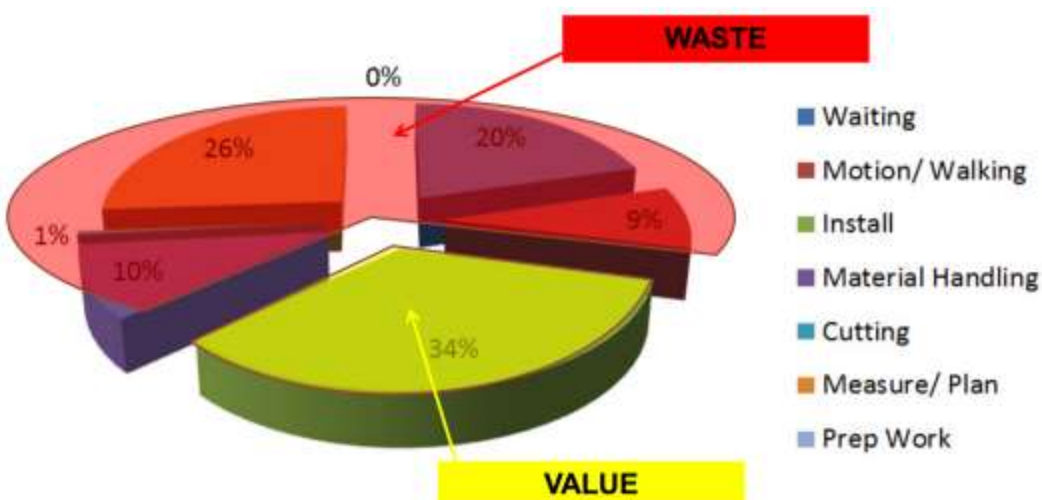


Figure 61: Waste vs. Value

Figure 62: Video Study of 2nd Floor Exterior

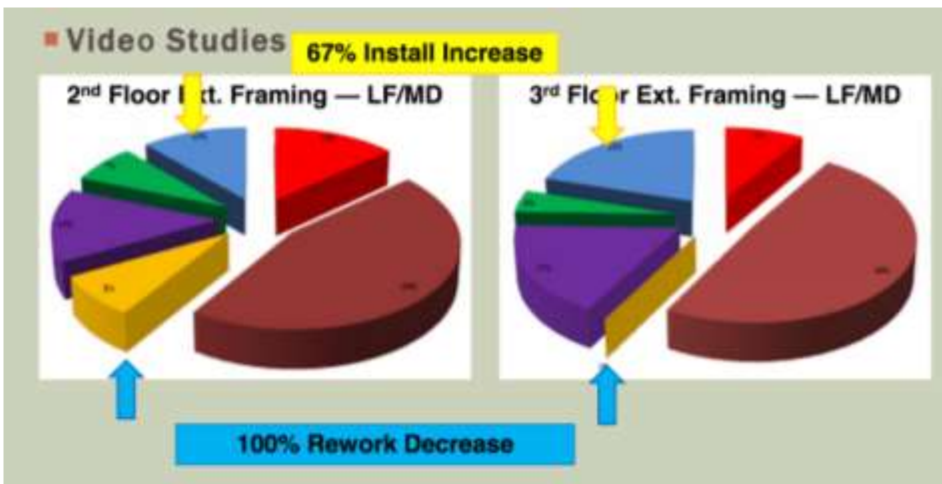


Figure 63: Resulting Improvement from Video Study

4.4.4 Process Mapping

The Temecula Valley team developed process maps for some of the most common activities. Figure 64 and Figure 65 show a process map for an RFI and Submittal. The goal of the process map is to make tacit knowledge transparent through documentation, to standardize their processes, and to seek opportunities for improvement from the current state.

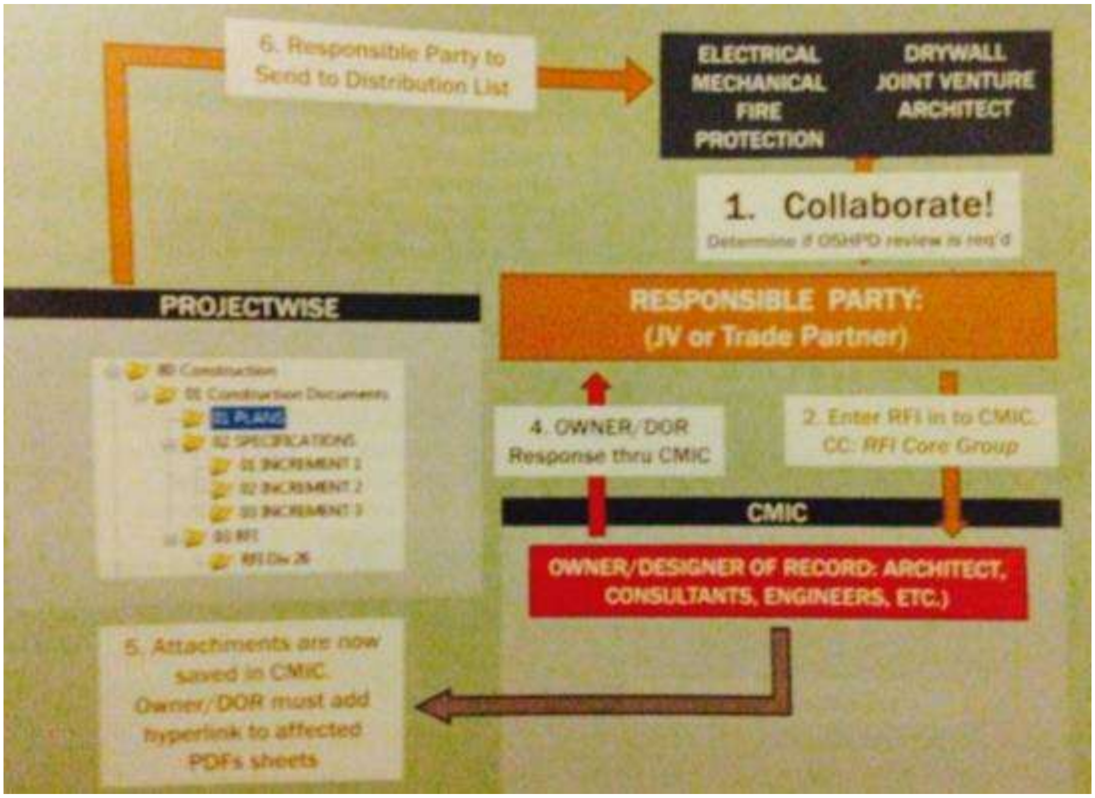


Figure 64: Process Map for RFIs

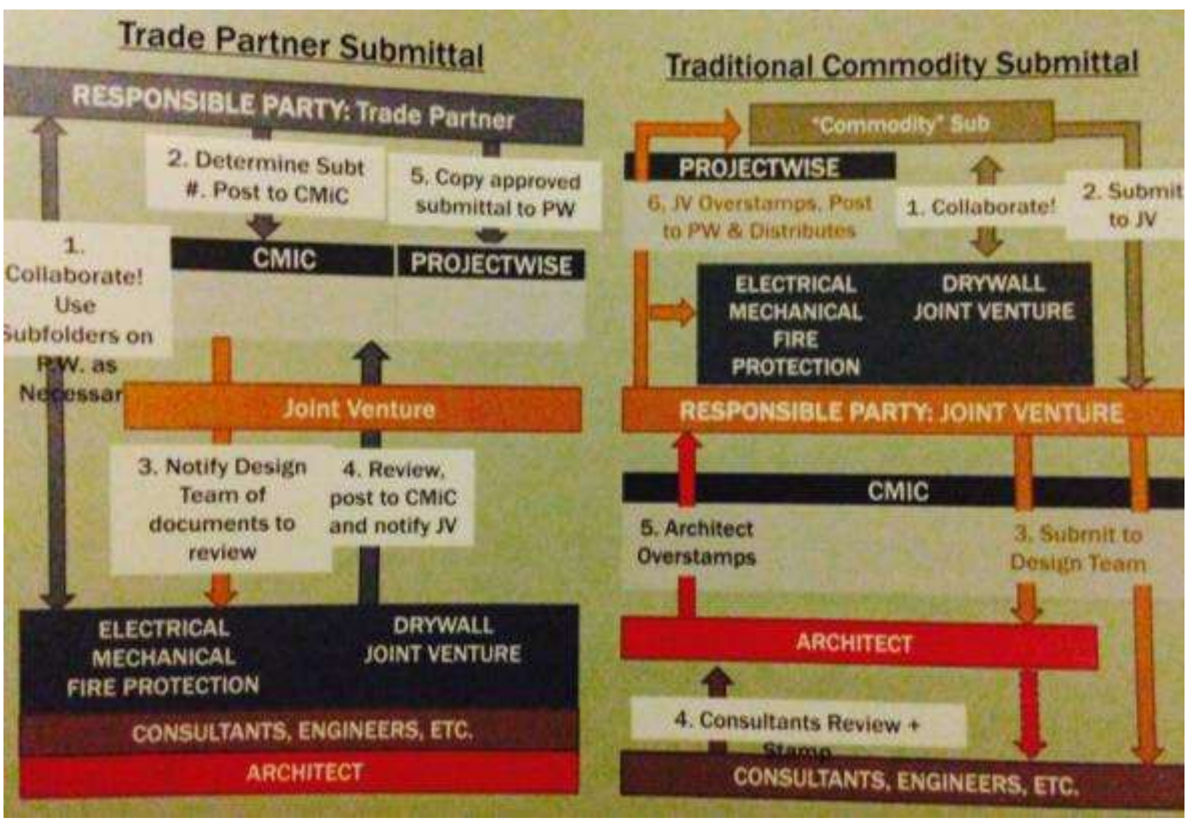


Figure 65: Process Map for Submittals

4.4.5 First Run Studies

In addition to the Value Stream Mapping studies, the field crew also conducted several first run studies. The first run studies allowed them to simulate the work either with mock-ups or through discussion to develop a plan for installing key components. Additionally, the first run studies allowed the team to collect preliminary data on labor productivity. Using the productivity data, the team could determine whether or not they can meet their productivity objectives and take corrective action early. They could also significantly reduce constructability risks and they can have better data of the overall prior to construction so they can better allocate their time and attention on the more risky scopes of work.

Figure 66: First Run Studies

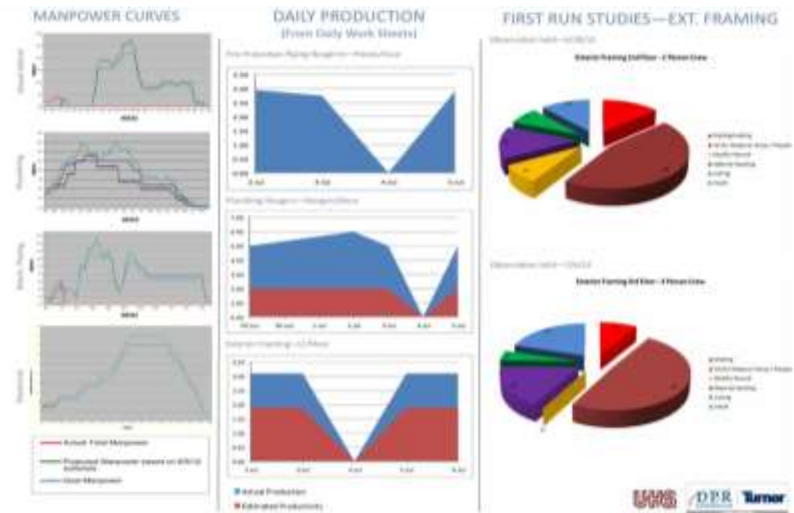


Figure 67: Production Rates and First Run Studies

4.4.6 5 Whys Analysis

The team used a 5 Whys Analysis to find the root cause of problems and take action to prevent the problem from occurring again in the future. The 5 Whys Analysis was used to diagnose and fix problems that can came up from the Last Planner's PPC tracking. Figure 68 shows a sample 5 Whys Analysis.

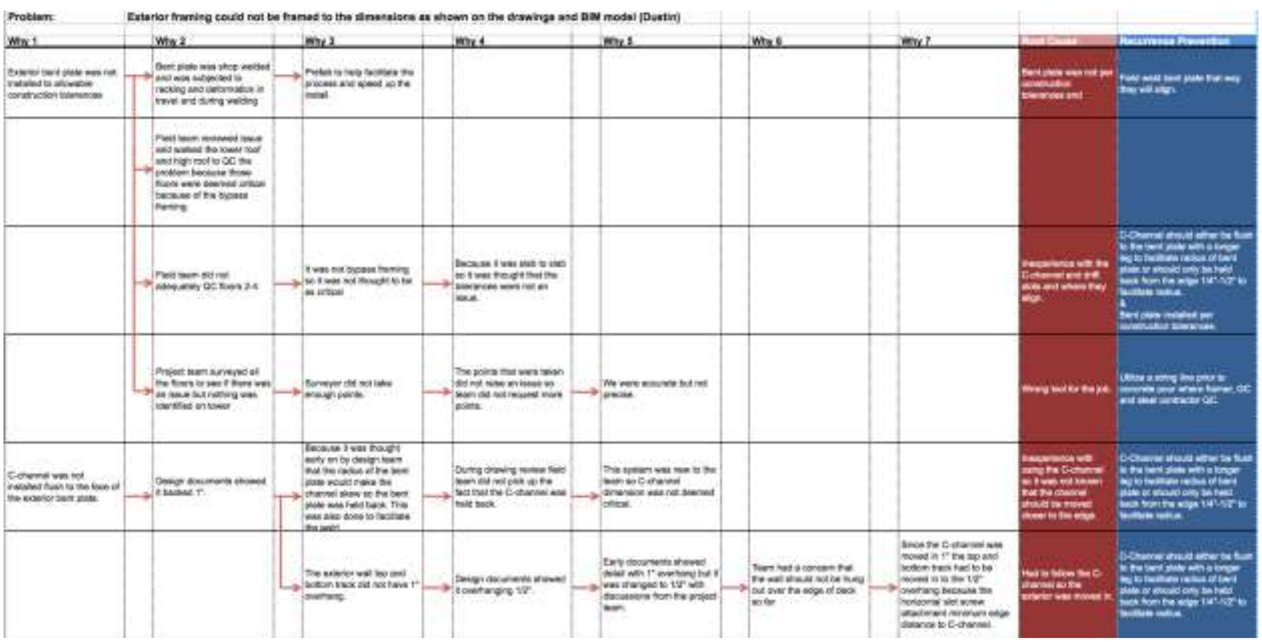


Figure 68: Example of 5 Whys Analysis

4.4.7 Community of Practice (COP)

To facilitate learning and sharing of knowledge on Temecula Valley, the team developed their own community of practice (COP). The community of practice was modeled after the Lean Construction Institute's Communities of Practice. The members in the COP members met once a month for approximately 1-2 hours. The goals of the COP are to promote knowledge sharing, sustain the Lean culture, and to get the people who are responsible for the daily project activities to advance Lean implementation. All the members in the risk pool had a representative within the COP and they each took turns in organizing the events. The COP events included a mixture of: (1) sharing internal best practices, (2) sharing lessons learned from another project, (3) having guests come to present information to the group, and (4) discussing Lean books that the team has been reading.

4.4.8 Shared Key Performance Indicators (KPIs)

This section documents the Key Performance Indicators that were recorded and shared with the Temecula Valley team. These KPIs appear in the monthly status updates to the owner (appendix 6.1). It is important to note that the KPIs first appeared in June 2012 – approximately 1 year after the start of construction. The reason for the shared KPIs to appear so late is that this was the first TVD project for most of the participants. Many of the practices of TVD are different that more traditional project delivery methods and it took some time to for the team to develop these KPIs.

The shared KPIs and shared financial tracking metrics were developed in response to Bill Seed's (the owner) question: "Are you going to make money on this project?" One of Bill's conditions of satisfaction for this project is for the team to make a reasonable profit. And although this might sound like an easy question to answer, it was big challenge for the team. Ken Lindsey from Southland (mechanical trade partner) rose to the challenge and developed a spreadsheet to integrate the team's spending, cost projections, and labor productivity rates. The main KPIs include:

- Financial Position
- Billed to Date
- Budget and Path to Budget
- Current Risks
- Schedule and Milestones
- PPC and Schedule Variance
- Man Power Curves
- Weekly Production Rates
- Monthly Rework
- Video Studies
- Lessons Learned / 5 Good Whys
- Project Photos
- Safety Metrics
- Inspection Metrics

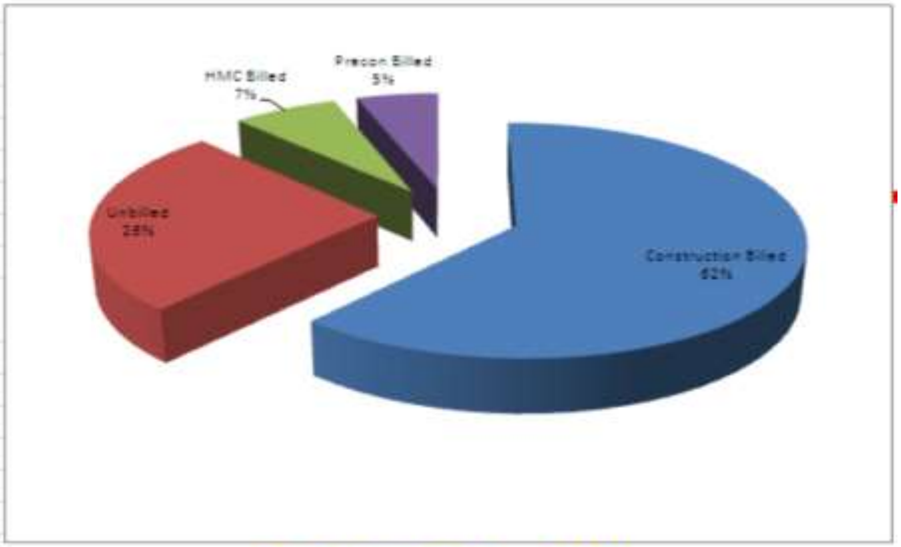
4.4.8.1 Financial Position

The financial position shows the team's current cost and profit projections. The goal of this KPI is to communicate with the team the current state of the project and to encourage the team to work together to drive down cost and increase their profits.

Figure 69. Financial Position

4.4.8.2 Billed to Date

The billed to date keeps track of the total amount that has been spent relative to the contract value. This metric gives the team a good indicator of how much of the project's remaining budget is still malleable.



Billed to Date - 72%

CONTRACT VALUE DELTAS

Team Member	PTCE Budget	Dec-12 Budget	Jan-13 Budget	Monthly Delta
Joint Venture (JV)	54,674,642	53,846,238	53,815,034	-31,204
Mechanical & Plumbing (MP)	24,615,454	23,380,129	23,200,129	-180,000
Electrical (E)	13,751,700	16,219,437	16,034,306	-185,131
Drywall & Framing (DF)	8,035,966	9,318,097	9,405,344	87,247
Fire Protection (FP)	1,231,721	1,280,939	1,280,939	0
Architecture (AR)	7,744,830	8,217,679	8,299,279	81,600

Figure 70. Billed to Date

4.4.8.3 Budget and Path to Budget

The path to budget is a list of opportunities that the team can still realize. The realization of these opportunities would allow the team to bring the project back to budget and increase profitability.

BUDGET

Risk to Contingency (ROMs)

Design Contingency Items

Item	Value	ROM/ Owner	Owner Item Cost
JV Landscape Drawing revisions to onsite roadway realignment, revised berms and horsetrail	60,000	ROM	
JV/A Helipad design/EIR changes/ Remove Old Helipad from Design	0	Owner Item	750,000
Team Nuc Med room changes	15,000	ROM	
E Cat 6 for EMS	3,000	ROM	
UHSR Potential ITIS overruns	45,000	ROM	
A Potential Changes in Endoscopy Room	2,500	ROM	
Team CVOR Change		ROM	1,000,000
Team - Cerner patient tracking boards (ACD # 034)	35,000	ROM	35,000
DF - Wall mounted laptop at Pyxis locations	13,266	ROM	13,266
Team - Coffee Shop Revisions	100,000	ROM	100,000
MP/E/DF - Changing Room 1210 to results pending/waiting room (SI # 65, ACD # 066/067), Room 1010 HIM Mods, Room 1264 Add power for treadmill	25,000	ROM	25,000
Team - Physical Therapy Room Changes (ACD # 071)	20,000	ROM	20,000
MP - Farwest ACD changes additional firestopping	50,000	ROM	
DF - F&V engineering ceiling services and additional CA	24,000	ROM	
DF - GFRG Columns	15,000	ROM	
E - Added equipment at the Kitchen Island	4,224	ROM	
E - ACD # 060 Added Roof Lighting	7,372	ROM	0
Factor for Unidentified Risks	1.00		
Suggested Design Contingency	419,362		
Current Design Contingency	419,362		
Delta Suggested vs. Current DC	0		

Construction Contingency Items

Item	Value	ROM/	Owner
JV - Potential Additional GC's due to extended closeout	147,500	ROM	0
Team - Additional IOR costs	300,000	ROM	0
JV - Projected overrun on the shared equipment yard	50,000	ROM	0
JV - Revisions to the splay wires ay compression posts	10,000	ROM	0
DF - Labor and Productivity Impact on remaining floors	223,216	ROM	0
DF - Productivity projected loss on taping	200,000	ROM	0
DF - Added material costs (ceilings) and equipment rental	130,000	ROM	0
JV - Labor to bring trash down in lieu of trash chute	20,000	ROM	0
JV - Change out roof screens to match new color	45,000	ROM	0
JV - Added molding at 1st floor roof	15,000	ROM	0
MP/JV - Added Heating for the floors (Labor and temp heaters) for 3 months	75,000	ROM	0
MP - Farwest Contract Overrun	50,000	ROM	0
DF - Additional rework since VSHO		ROM	
Agency	230,000	ROM	0
Escalation	15,000	ROM	0
QA/QC	197,000	ROM	0
Subtotal	1,707,716		
Factor for Unidentified Risks	1.00		
Suggested Construction Contingency	1,707,716		
Current Construction Contingency	1,707,716		
Delta Suggested vs. Current CC	0		

PATH TO BUDGET

JV Savings in Cost to Complete (Steel, Misc Metal, Stone, Rough Carpentry)	50,000	02/19/13
Team Construction Contingency Savings of QA/QC item	25,000	02/19/13
Team Construction Contingency Savings of Escalation item	15,000	02/19/13
MP - Heating Hot Water Piping Productivity	100,000	02/19/13
MP - Med Gas Productivity	85,000	02/19/13
MP - Plumbing Fixture Buyout	65,000	02/19/13
JV Savings in GC's	45,000	03/19/13
MP Plumbing Material handling labor savings	50,000	03/19/13
Team Construction Contingency Savings of QA/QC item	25,000	03/19/13
JV Savings in Cost to Complete (Roofing, Insulation, Caulking, Doors, Fire proofing, Millwork, Flooring, Painting)	170,956	03/19/13
A to target $22,500 reduction in reimbursable costs	22,500	03/19/13
Team Construction Contingency Savings of Agency impact	100,000	03/19/13
MP - Plumbing Material Copper Bulk Buy	80,000	03/19/13
MP - Plumbing Seismic Productivity	110,000	03/19/13
MP - Sheet Metal Productivity	75,000	03/19/13
DF Potential Productivity savings on Projections	60,000	04/16/13
MP Plumbing Fixture Set Productivity Gains	40,000	04/16/13
Team Construction Contingency Savings of QA/QC item	16,400	04/16/13
Team Construction Contingency Savings of QA/QC item	16,400	05/21/13
MP PM savings	50,000	05/21/13
E Labor Productivity Savings	50,000	05/21/13
E Material buyout Savings	75,000	05/21/13
JV Savings in GC's	45,000	06/18/13
JV Savings in Cost to complete (Painting, Glazing, Kitchen, DFC)	50,000	06/18/13
Team Construction Contingency Savings of QA/QC item	16,400	06/18/13
A to target $22,500 reduction in reimbursable costs	22,500	06/18/13
Team Construction Contingency Savings of Agency impact	100,000	06/18/13
Team Construction Contingency Savings of QA/QC item	16,400	07/16/13
Team Construction Contingency Savings of QA/QC item	81,400	08/20/13
Team Construction Contingency Savings of Agency impact	30,000	08/20/13
Team Savings on Permit Matrix	30,000	08/20/13
Team Savings on OSHPD Permit Costs	150,000	09/30/13
Subtotal	1,887,556	
Additional Reduction in **DC** and/or **CC** required	322,395	
Total	2,209,951	
UHS Owner items recognized and potentially used if required at end of job	1,563,270	10/01/13
Total	3,773,221	

Path Back Items Realized This Month—$750,000.00

Team Target current schedule savings in GC's	35,000
Team Construction Contingency Savings of Schedule item	50,000
Team Construction Contingency Savings of QA/QC item	25,000
JV Savings in Cost to Complete (Roofing, Survey, Landscape)	100,000
Team Construction Contingency Savings of Agency impact	100,000
E to target 6% in labor productivity gains	75,000
E to target 4% general conditions cost reduction	45,000
MP Savings in Plumbing Field Supervision	100,000
MP Sheetmetal duct install productivity gains	20,000
MP Mechanical Piping productivity gains	30,000
E to target 5% in material buyouts	75,000
Team Construction Contingency Savings of Schedule item	50,000
Team Construction Contingency Savings of Schedule item	25,000

Path Back Items Realized to Date

$3,277,418.00

Figure 71. Path to Budget

4.4.8.4 Current Risks

The current risks KPI lists the major risk items.

CURRENT SCHEDULE RISKS
Inclement Weather
Stairwell 1 & 2 Issues

WEATHER DAYS THIS MONTH	SCHEDULE IMPACT	TOTAL RAIN DAYS
0 days	3 days	5 days

Figure 72. Current Risks

4.4.8.5 Schedule and Milestones

This KPI tracks the key schedule milestones of the project.

SCHEDULE & MILESTONES

ORIGINAL SCHEDULE

APPROVED SCHEDULE (W/ ESA EXTENSION)

CURRENT SCHEDULE

WEATHER DAYS THIS MONTH	SCHEDULE IMPACT	TOTAL RAIN DAYS	CURRENT SCHEDULE RISKS
0 days	3 days	5 days	Inclement Weather

SCHEDULE & MILESTONES

CONSTRUCTION ACTIVITIES COMPLETED THIS MONTH	CONSTRUCTION ACTIVITIES CURRENTLY IN PROGRESS	CONSTRUCTION ACTIVITIES STARTING WITHIN 30 DAYS
SOG Substrate	SOG Substantially Complete	Fireproofing on 1st and 4th floors
5th Roof Concrete Deck	Exterior Framing begins	Wall layout on 1st floor
Begin 2nd & 3rd floor wall layout	Fireproofing levels 2 & 3	Overhead utilities on 2 & 3

MILESTONES	ORIGINAL SCHEDULE	APPROVED SCHEDULE	ACTUAL
Building Pad Complete	8/26/2011	11/11/2011	11/4/2011
Begin Steel Erection	11/18/2011	2/13/2012	2/13/2012
Top Out	12/30/2011	3/22/2012	3/22/2012
First Deck Pour	3/8/2012	5/3/2012	5/1/2012
Dry -In Building	7/20/2012	11/7/2012	
Substantial Completion	5/28/2013	8/22/2013	
Department of Health Services Licensing		10/22/2013	
First Day Patient		10/23/2013	

Figure 73. Schedule Milestones

4.4.8.6 PPC and Schedule Variance

PPC and Schedule Variance are metrics of the Last Planner. PPC measures the degree to which commitments in the weekly work plan are met.

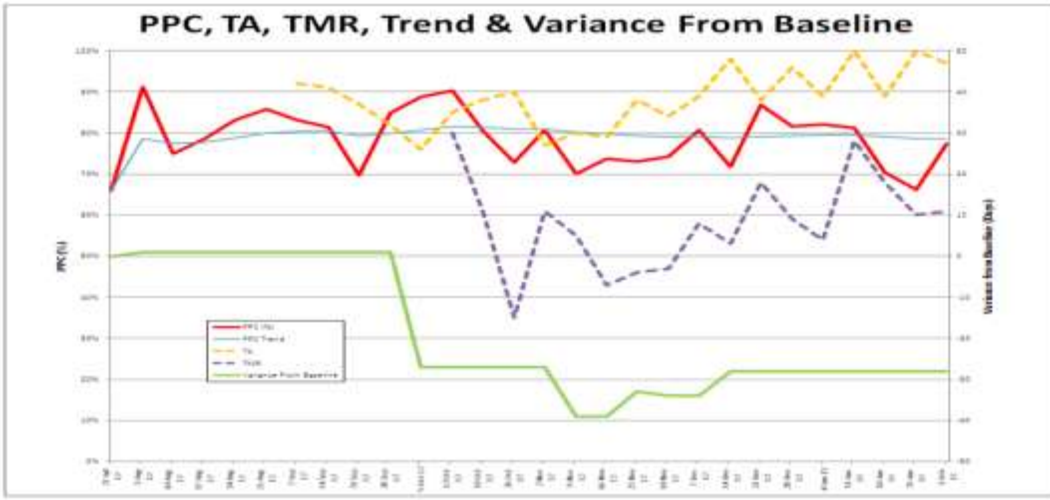


Figure 74. PPC Trends

4.4.8.7 Man Power Curves

The man power curves includes the projected and the actual labor hours of each trade.

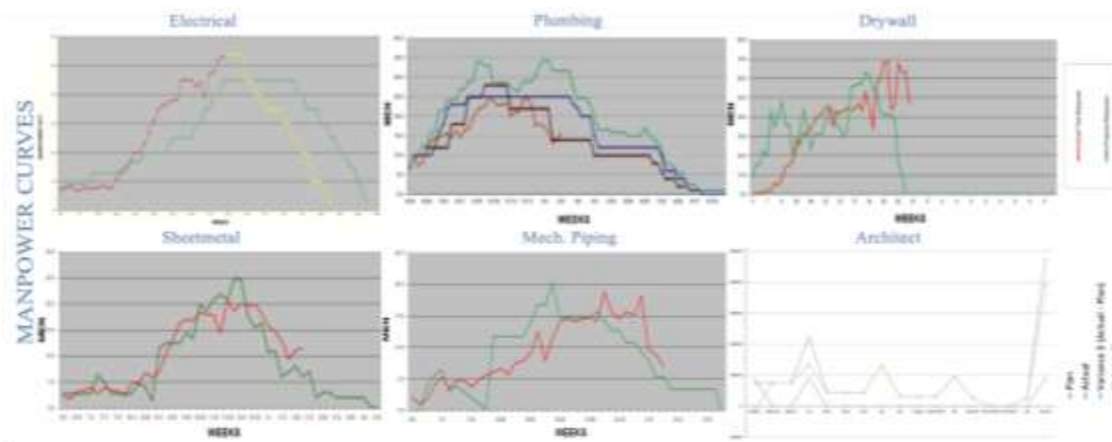


Figure 75. Man Power Curves

4.4.8.8 Weekly Production Rates

The team tracked their production rates for each crew on a weekly basis. The actual production rate is compared with the estimated or target production rate, which was set at the beginning of the project. The production rate tracking revealed that their Lean operations in the field had a positive effect of the crew's productivity rates. This metric was key in allowing the team to forecast their anticipated cost to completion in the construction phase.

DESCRIPTION	UNIT	BUDGET	ACTUALS TO DATE	% SAVINGS	% COMPLETE	5-Oct-12	12-Oct-12	19-Oct-12	26-Oct-12	2-Nov-12	9-Nov-12	16-Nov-12	23-Nov-12	30-Nov-12
Sheetmetal														
CAV Install	EA/MD	2	2.5	25%	89%	2	1	3.3	1.6	3.5	2.3	2.2	5	1.9
Round ductwork	LF/MD	35.2	41	16%	100%	21	27	40	34.6	34.4	66.4	48.8	106	70.8
Rectangular ductwork	LF/MD	14.5	21	45%	91%	15	16	18	14.2	23.5	17.2	50.6	18.9	144
Mechanical Piping														
OH HHW Copper Piping	LF/MD	37	72	95%	100%	83		–	57	39	37	198	123	97
OH Black Victaulic Piping	LF/MD	11	58	436%	83%	71		–	60	39	–	–	–	40
CAV Hookups	HRS/EA	5	6	20%	100%	6		–	6	2.6	4.4	6	4	5
Plumbing														
Copper	LF/MD	42.8	45	6%	93%	58		40	33.3	78.5	72.3	90.3	77	29
Medical gas	LF/MD	28.9	51.8	79%	103%	40	40	24.1	41	119	65.3	75	98	68
Seismic	HRS/EA	3	1.4	67%	98%	2		1.3	1	1.2	1.1	–	1.9	–
Carriers	HRS/EA	2	1.2	40%	72%			1.66	0.52	1	3.8	1.8	–	–
Electrical														
3rd Floor Med Surge Complete Rough-in and	HRS/RM	24	20.5	15%	100%	20.5	20.5	20.5	20.5	19	20	22	22	22
4th Floor Med Surge Complete Rough-in and	HRS/RM	24	21	13%	100%	–	–	18	17	17	18	22	22	22
5th Floor Med Surge Complete Rough-in and	HRS/RM	24	19	21%	100%	–	–	–	24	20	20	21	22	21
Drywall														
1st Floor Priority Walls	LF/MH	1.3	2	54%	93%	1.6	–	1.8	–	–	–	2	–	–
1st Floor Top Out Board	SF/MH	41.5	32.3	-22%	93%	35.1	–	31.5	–	–	–	53.3	25.6	34.5
1st Floor Hang Drywall	SF/MH	61.3	57	-7%	90%					–	–	75.8	–	–
1st Floor HM Frame Install	EA/MH	0.5	0.3	-40%	33%					–	–	0.2	0.1	1.7

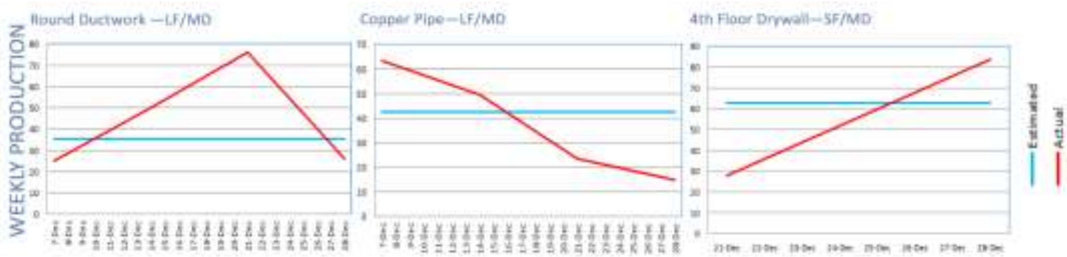


Figure 76. Weekly Production Rates

One of the advantages of tracking labor productivity on a weekly basis is that the team can experiment with their production system (the batch sizes, work packages, crew sizes, etc.). The rapid feedback between action and result means that the team could run small experiments to uncover hidden nuggets for improving productivity. Instead of rely on heuristics, myths, and our assumptions of productivity; the experiment-based approach uses real to inform decisions.

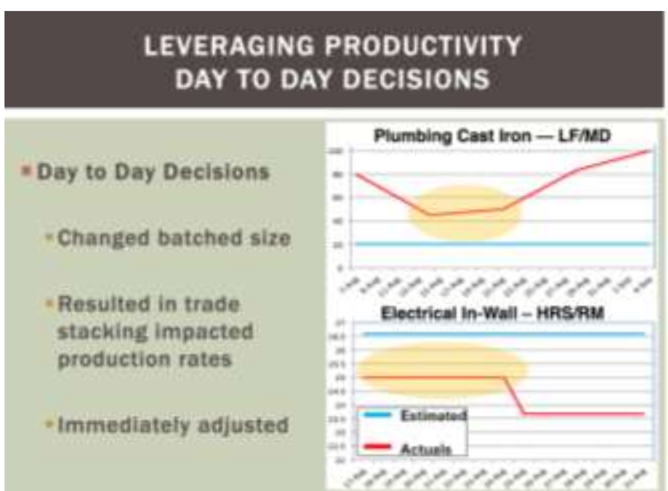


Figure 77: Leveraging Productivity Data for Day to Day Decisions

Using their productivity data, the team decided to re-sequence the work of the drywall and the cast iron trades. They decided to install plumbing before framing contrary to the traditional method. This sped the overall process and although the cost increased for drywall and framing, the team saved an estimated

$200,000 in plumbing costs. The team was only able to make this change in the work sequence because they had modeled all of the framing studs and had very good data on the production rates.

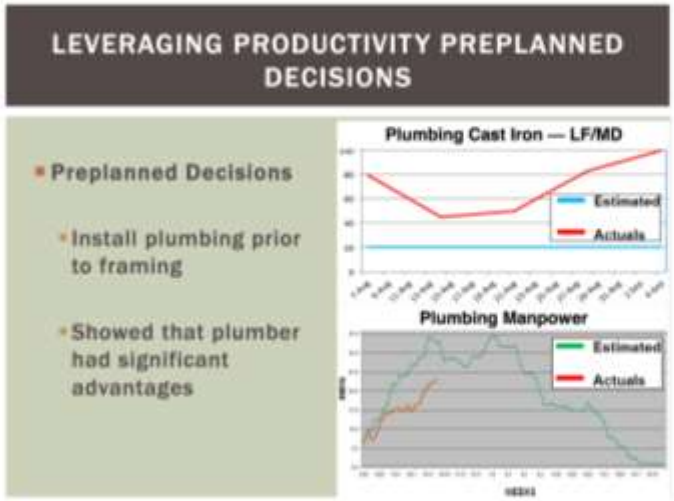


Figure 78: Leveraging Productivity Data for Preplanned Decisions

For the Med-Gas trade, the team found that they were more productive when they worked over-time. The conventional way of thinking is that productivity decreases with over-time work. This trade required a significant amount of set up and set down time and their scope of work required intense concentration. By working overtime, the Med-Gas had longer stretches of productivity, higher rates of tool time, and a quieter working environment during the after hours.

Figure 79: Leveraging Productivity Data for the Work Week

4.4.8.9 Monthly Rework

The team tracked the rework of the electrical, plumbing, drywall, and HVAC trades and included this information in the monthly report. The goal of the rework tracking is to use the 5 Whys Analysis to identify the root causes for why these rework items occurred so that they could take preventative action. According to the team's documents, they observed 592.5 labor hours of rework, which is equivalent to

$38,512.50 (assuming $65 per labor hours). It is unclear exactly how much cost savings were realized from this practice since that information was not documented.

MONTHLY REWORK

Date	Hours	Trade	Description	Reason	5 Why Scheduli
1-Oct	10	Drywall	Uncoordinated duct openings at CUR	Openings were added after model was completed. There was a note on the drawing to coordinate however it was missed.	Yes
1-Oct	10	Drywall	Changed out 20 ga. Studs to 18 ga. For crash railed missed at the 1st floor	Crashrails were missed by F&W or HMC	No
1-Oct	13	Drywall	Added 4 carriers that were not modeled on level 2	Missed in the model	No
1-Oct	6	Drywall	Studs were missing in a bay of wall. The bottom track was not marked	Layout guy missed	No
15-Oct	8	Drywall	1st floor exterior replace sheathing at HM frames	Sheathing should have been cut more to facilitate door frame install.	
15-Oct	16	Drywall	2nd floor nurse call rework above doors	Uncoordinated in BIM model. Was not placed	
15-Oct	16	Drywall	5th floor fixing top track at jamb studs	Extended z-clips to far out and jamb studs could not go to the deck. Z-clips cut back.	

Figure 80. Monthly Rework

4.4.8.10 Implemented Improvements

The team shared a list of their key improvements in the monthly reports. The goal of the improvements announcement was to commend the efforts of those who came up with new ideas and to encourage all the people on their projects to innovate.

Drywall

- Use Sprayer for final pass on Level 4 Finish will improve productivity.

Figure 81. Implemented Improvements

4.4.8.11 Lessons Learned / 5 Good Whys

The team reported their key lessons learned and results from their 5 whys analysis to the monthly report.

Perform '5 Why's' quicker so that the lessons learned can be implemented sooner. Some opportunity has been lost by not doing this.	5 Why Issue - Humidifier piping had to be re-piped because it conflicted with the elevation of the beam/fireproofing. Piping is gravity feed.
Have pull plans mid-morning in lieu of early. This helps the constructors to start their crews first and then focus on pull plan.	Root Cause—FP was sprayed on too thick in some places coupled w/ some construction tolerances created perceived elevation bust.
Maintain continuity in clusters from design through construction. Have a handoff as people change during the project.	Recurrence Prevention—Issue and explain FP shop drawings to all effected trades. FP could have been scraped in lieu of re-piping.
Reflection was performed on the check-in process. Some items that came out were to make it electronic and combine with pull plan.	
Combine constructor and design pull plan in lieu of separate times.	

Figure 82. 5 Good Whys

4.4.8.12 Project Photos

Figure 83. Project Photos

4.4.8.13 Safety Metrics

SAFETY LOG

TOTAL MAN HOURS	RECORDABLES	FIRST AID	LOST TIME	NEAR MISS
222340	01	8	0	0

Figure 84. Safety Log

4.4.8.14 Inspection Metrics

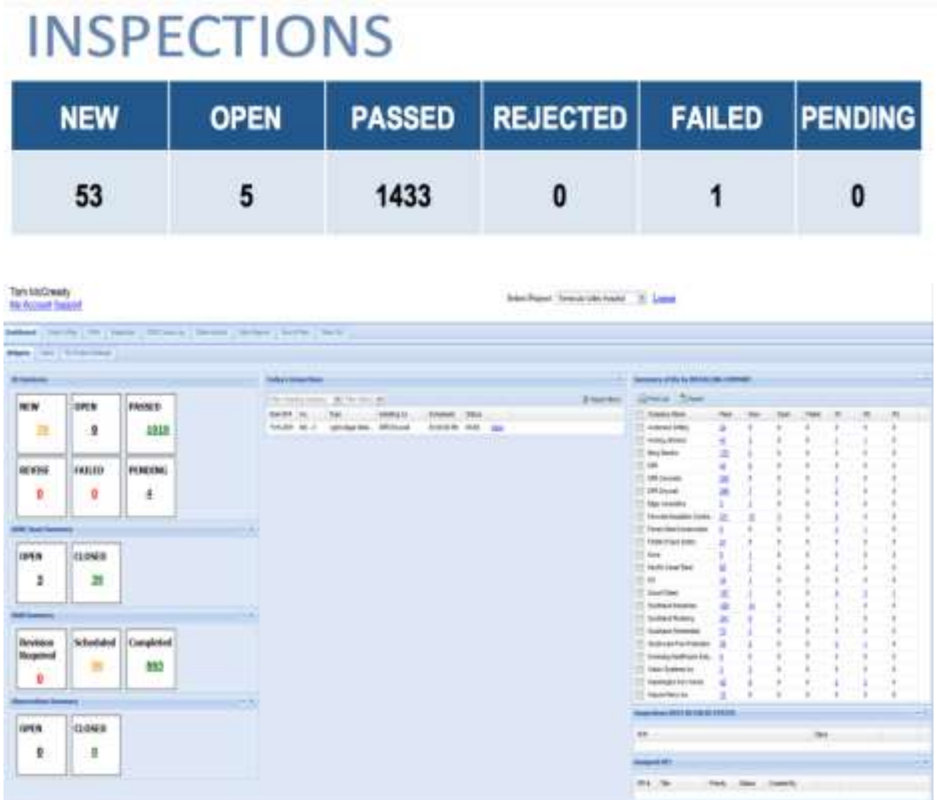


Figure 85. Inspection Metrics

5 Project Performance Metrics

5.1 Cost

The Temecula Valley Project began with a very aggressive Target Cost. According to the project team, the Temecula Valley project was completed for $480 / SF which is 30% less than the average for California hospitals (Figure 86; Figure 87). In terms of the cost per patient bed, the Temecula Valley project reported a cost $1.1 million per bed compared the $1.8 million per bed average in California even though the Temecula Valley project had private rooms and window views in each room. The cost savings came from a rigorous examination of what was truly valuable to the owner, more thought-out design, less waste in the design process, prefabrication of building components, and increased labor productivity in the field due to first run studies and value stream mapping.

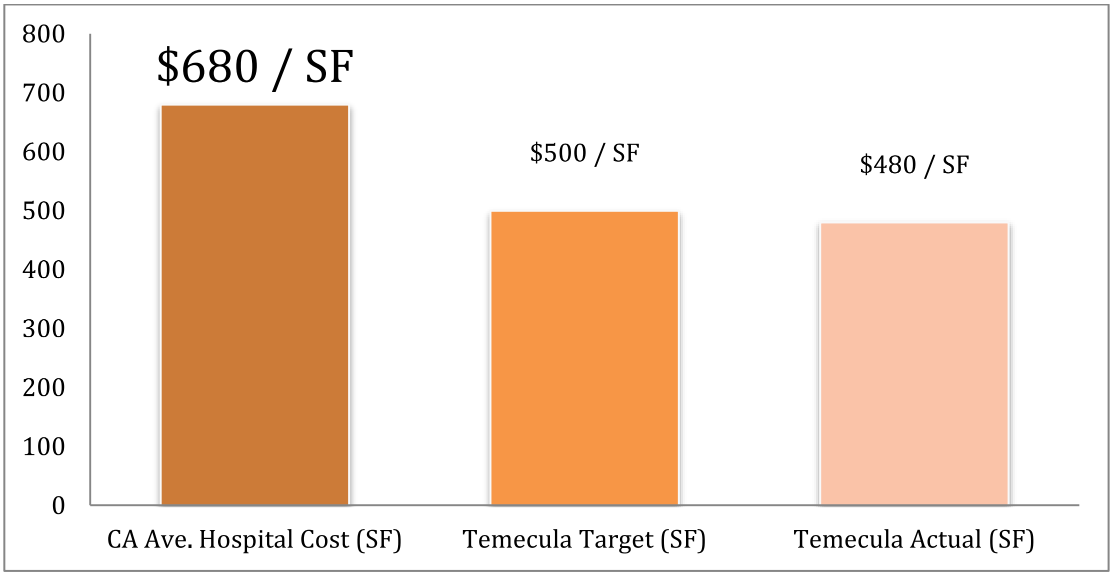


Figure 86: Cost per sf

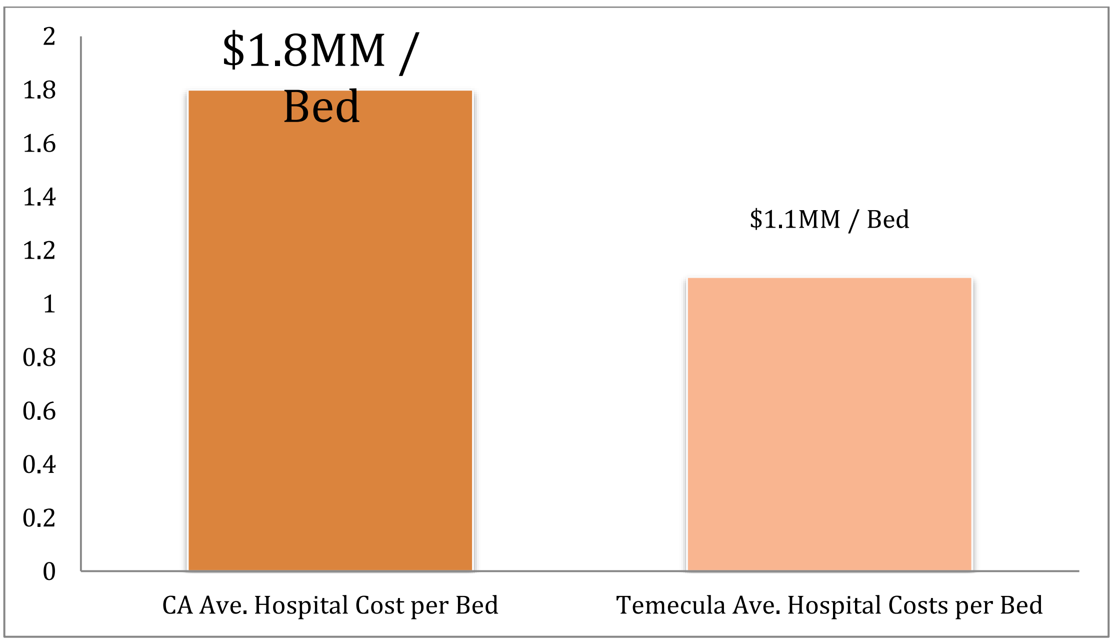


Figure 87: Cost per patient bed

5.2 Schedule

The project was completed a month-and-a-half ahead of schedule despite 82 days of delay due to environmental conditions (DPR, 2014b). The total duration was 18 months for the preconstruction phase and 2 years for the construction phase (DPR, 2014b).

5.3 Quality

According to interviews with 2 owner representatives, UHS is very happy with their project. They set aggressive targets in terms of cost, quality, and scope and were able to achieve them. The owner commented that the biggest thing they wanted from the project delivery method was reliability and cost control, which they achieved through this project. Since this research is solely focused on the design and construction phase, we did not investigate the quality of the facility from the perspective of the doctors, nurses, and patients. Future research is needed to examine the quality of projects that use TVD and IPD with projects that do not use these practices. Post occupancy studies will be performed to determine whether or not the TVD process truly delivered the intended value to the users and patients.

5.4 Safety

Safety is an important metric for any project. According to the Temecula Valley team, out of 407,958 man-hours there was 2 recordable events, 13 first aid incidents, 0 lost time, and 2 near miss (Figure 85). One thing worth noting is that the number of recordable and near misses are the same (2 each). Typically, the difference there is one or two orders of magnitudes between the number of near misses and the number of recordable. Limited information about the safety program at Temecula Valley and how they recorded violations restricts further conclusion on these results. Construction safety is difficult to track because it depends on the person tracking it and the criteria used to measure safety violations.

SAFETY LOG

TOTAL MAN HOURS	RECORDA-BLES	FIRST AID	LOST TIME	NEAR MISS
407958	2	13	0	2

Figure 88: Safety Log

5.5 Productivity

Productivity was tracked for every trade and publicly shared with the team. Overall, the productivity of the project, through the implementation of Lean in the field, was greater than the projected productivity. The median labor productivity were:

Sheet Metal: + 16%

Mechanical Piping: + 77%

Plumbing: + 46%

Electrical: + 16%

Drywall: - 7%

In some areas, the drywall trade was less productive than they had planned. This phenomenon may be due to: (1) the practice of optimizing for the whole rather than for each individual scope and (2) being too optimistic about the anticipated labor productivity rate. For example, some trades might sacrifice their productivity if it helps the overall project be completed faster. Overall, the priority trades such as sheet metal, mechanical, plumbing, and electrical all had labor savings while the drywall trade (which has a lower labor cost) took a hit. In the example below, the Mechanical crew installing the black Victaulic piping finished the project over 4 times faster than their initial estimate. A project manager from the Joint Venture remarked that the drywall trade set the bar too high, which resulted in the final productivity rate looking less favorable than it should. It is important to note that these productivity metrics were measure based on the difference between the actual rates and the budgeted rate. As more data is gathered, we intend to do a comparison with other projects with similar scopes of work.

PRODUCTIVITY					
DESCRIPTION	UNIT	BUDGET	ACTUALS TO DATE	% SAVINGS	% COMPLETE
Sheetmetal					
CAV Install	EA/MD	2	2.5	25%	89%
Round ductwork	LF/MD	35.2	41	16%	100%
Rectangular ductwork	LF/MD	14.5	21	45%	91%
Grills and registers	HR/EA	1	0.94	6%	59%
Roof Duct	LF/MD	10	8	-20%	100%
Mechanical Piping					
OH HHW Copper Piping	LF/MD	37	72	95%	100%
OH Black Victaulic Piping	LF/MD	11	59	436%	83%
CAV Hookups	HRS/EA	5	4	20%	100%
Equipment Hookup	HR/EA	94	39	59%	100%
Plumbing					
Copper	LF/MD	42.6	45	6%	93%
Medical gas	LF/MD	28.9	51.8	79%	103%
Seismic	HRS/EA	5	1.9	97%	98%
Carriers	HRS/EA	2	1.2	40%	72%
Fixture Set	HRS/EA	5	2.8	46%	42%
Electrical					
2nd Floor ICU Complete Rough-In and Wire	HRS/RM	26.5	23	13%	100%
2nd Floor ICU Light Fixture Install	HRS/RM	12.3	12	2%	100%
3rd Floor Med Surge Complete Rough-In and Wire	HRS/RM	24	20.5	15%	100%
2nd Floor ICU Finish Device	HRS/RM	12.5	9.3	26%	100%
3rd Floor Med-Surge Light Fixture Install	HRS/RM	13	11	15%	100%
3rd Floor Med-Surge Finish Device	HRS/RM	11.2	8.5	24%	100%
4th Floor Med Surge Complete Rough-In and Wire	HRS/RM	24	21	13%	100%
4th Floor Med-Surge Finish Device	HRS/RM	11.2	8.7	22%	100%
4th Floor Med-Surge Light Fixture Install	HRS/RM	13	10.4	20%	92%
5th Floor Med Surge Complete Rough-In and Wire	HRS/RM	24	19	21%	100%
5th Floor Med-Surge Light Fixture Install	HRS/RM	13	10.9	16%	90%
5th Floor Med-Surge Finish Device	HRS/RM	11.2	9.4	16%	85%
Drywall					
1st Floor Priority Walls	LF/MH	1.3	2	54%	93%
1st Floor Top Out Board	SF/MH	41.5	32.3	-22%	93%
1st Floor Hang Drywall	SF/MH	61.3	57	-7%	90%
1st Floor HM Frame Install	EA/MH	0.5	0.3	-40%	33%
1st Floor Level 1 Taping Top Down	SF/MH	39.6	262	562%	82%

Figure 89: Labor Productivity

5.6 Profitability

Due to the cost savings in both the design and construction phase, the members of the risk pool were able to earn 150% of their negotiated profits, which was the maximum amount of profit that they could earn on the project. Out of $111 of their at-risk-work, companies earned $6 million in net profit, which is a pre-tax net profit margin of 5.1%. We currently do not have enough information to conclude how this profit margin compares with the industry average for a similar project. It is also important to note that the net profit margin is an aggregate of all the TVD/IPD members. For confidentiality purposes, we do not publish the profit margins of specific firms. It is worth noting that the profit margins of designers are higher than that of contractors. Contractors have labor, materials, and equipment while the designer's main cost is labor.

5.7 Cultural Outcomes

In order to capture the cultural outcomes of the project, the researcher sent out survey to the Temecula Valley participants. The survey questions are based on Sutter Health's 5 Big Ideas. The questions were sent out in a randomized shuffle order, which eliminates the bias that can result from the sequence of the questions. Each participant was asked to rate on a Likert Scale to the extent that they believe the statements of Sutter's 5 Big Ideas were true for the Temecula Valley project. The scales for the responds are as follows:

1 => Strongly Disagree

2=> Disagree

3=> Neither Agree nor Disagree

4=> Agree

5=> Strongly Agree

In total 6 participants answered the survey and the mean score of their response is shown in Table 7.

Table 7: Cultural Survey Summary

Cultural Outcomes Survey (rated on a scale of 1 to 5)	Mean
1. The team collaborated, "really" collaborate	5
2. The project was optimized for the whole rather than optimized for local maxims.	**4.8**
3. The team tightly coupled learning with action	**4.5**
4. The project was managed as a network of commitments	4.1
5. Long lasting friendships and trust were formed as a result of this project.	5

The cultural survey showed very positive results. Four out of the five questions received a mean score greater than or equal to 4.5. The survey revealed the management of the project as a "network of commitments" is one area for improvement.

Often times project outcomes only measure the dimensions of scope, schedule, and cost. The human dimensions of project success in terms long last friendships, rapport, relationships, and trust may be just as important as the scope, schedule, and cost outcomes. Many of the participants will be working together on future projects and the trust that they build on this project will carry over to their next project. This survey showed that in addition to achieving the aggressive goals of the project, the team was also able to build long lasting personal and professional relationships. The Ah Ha Moments, which documented the team's learning and reflection on their lean practices, showed some evidence of the positive cultural outcomes that came from the Temecula Valley project. Below are some examples:

"I was touched by the threading emails showing compassion and concern about our team member." – General Contractor

"This was the best project in years." - Mechanical Trade Partner

"I feel that the people in the big room are friends". - Architect

"I reflected on the project during the holiday break and felt that it hasn't consumed me as with other projects. There were no worries." – General Contractor

"Once you are exposed to a lean project, you wish that all your other projects work this way." – Architect

"At my office, my colleagues told me that I have changed. My thought process and procedures truly reflected the big room culture." – Mechanical Trade Partner

" I was able to create a pull plan for a dinner for my wife. The dinner was very successful and well organized." – Trade Partner

5.8 Product Innovations

The Temecula Valley team generated numerous innovations. Below are some examples of product innovations that were documented in the monthly reports.

- Electrical

- Plug tail device in lieu of standard plugs. Plugs only have to be connected on the backside reducing labor and troubleshooting

General

- Carnie Hooks are being used for cord management. Inexpensive option and can be handed out to workers. $3.00/ea.

Drywall/Framing

- Utilize low torque screw guns for backing due to heavy gauges.

- Sheet metal made a shroud for the chop saws in lieu of the dens board to catch sparks/debris.

- Extension for roto hammer/torque wrench to install soffit top track anchor bolts. Made in the field by JM.

Electrical

- Feeders for distribution boards are grouped together on one reel by the manufacturer.

Utilized dust muzzle bought from local store to mitigate dust from concrete cutting. This item costs approximately $60.00. Similar products sold by Hilti are $1000 +

https://www.dustmuzzle.com/dust_collection/saw_muzzle.php

5.9 Process Innovations

In addition to the product innovations, there were many process innovations / improvements that reduced cost and increased the productivity.

Implemented Improvements

- Drywall/Framing
    - 4th & 5th floor kick off meeting. The same crews that are doing 2nd and 3rd are doing 4th and 5th.
- Mechanical/Plumbing

- Filed down drill bit so that when the drilled is pulled away the bit separates.

- Electrical
    - Tracking labor differently from productivity report outs and will utilize moving forward

- Visuals for backing locations to ensure correct locations

Electrical

- Utilizing quarterly field surveys helps improve communication and extract ideas.
- Lead man coordination meetings in lieu of just GF's to improve communication.
- Utilizing Apple Facetime to quickly communicate a visual to engineers.

- Having lunch with all workers is adding value by spurring incremental innovation and increasing transparency with the entire project. Most workers have not had this forum previously.
- To protect prefab showers a sprayed on latex is going to be utilized. This idea was brought forth by the insulator. The question was proposed to the entire project and we received close to 20 ideas.

Electrical

- Taking pictures with notes in them so that when the picture is issued to the field it is known what needs to be done.

Drywall

- Use Sprayer for final pass on Level 4 Finish will improve productivity.

- Use a group washout for taping operations

General

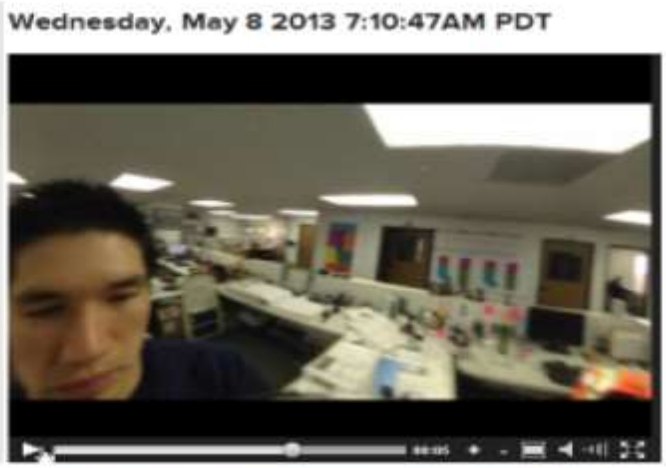
- Utilize dashboard to reach information on the project more efficiently.

  http://www.uhsprojects.com

Immersive Media

360 degree interactive project tour. HD quality.

http://d2r78545clah05.cloudfront.net/Turner2/index.html



Utilize GoPano to record low quality 360 degree videos on the site. This is simple to use for field staff and good way to quickly communicate project progress.

http://www.gopano.com

VBI Door delivery—Based on last months delivery video they were able to reduce double handling and save 30 hours of delivery time on one floor. This was from the 3rd floor to the 4th floor.

Figure 90: Garage Door

Typically the drywall framers would begin work after the mechanical trades. After the framing is completed, the electrical trades would come in and install the lighting fixtures and then remaining trades would come in and finish up the room. On this project, the team decided to spend more money to build a garage door system between the rooms. The garage doors allow framing drywall top out prior to large ductwork. It also creates a scissor lift path of travel from room to room. The inclusion of the garage door initially cost more money. This is an example of designing for constructability because the team spent more money on the materials but gain back greater returns on the labor productivity. This innovation was only possible due to TVD because the builders were able to work with the designers in the early stages of the project.

Figure 91: Using iPads to Document RFIs, Rework, and Change Orders

In order to expedite communication of RFIs and change orders, the team used iPads and photo-sharing applications to document problems.

Figure 92: Masking Top Track Prior to SFRM

They used a piece of blue painters tape and masking off the slots of our toptrack prior to Sprayed-Applied Fireproofing. Afterwards they can easily remove the tape and discard the overspray without having to chip and scrape the overspray from our top track. This saves labor on scrapping and cleaning, which would eventually follow.

Figure 93: Screeding Z-Clips

The drywall team installed Z-Clips to the thickness of the Spray-Applied Fireproofing. This allowed them to have the SFRM sub screed the bottom of the beam flat with the surface of Z-Bar. The benefit is that now when they install toptrack to the Z-Bar they don't have to scrape the monokote and sweep up. All the screeding waste is picked up in the fireproofers tarps.

Figure 94: All Materials on Carts

All the materials on-site are required to be on carts. The Temecula Valley team had a 30/30 rule. All materials on carts must be within 30 seconds or 30 feet from the installation site. This rule made sure that the materials were located near the scope of work and prevents people from hoarding space.

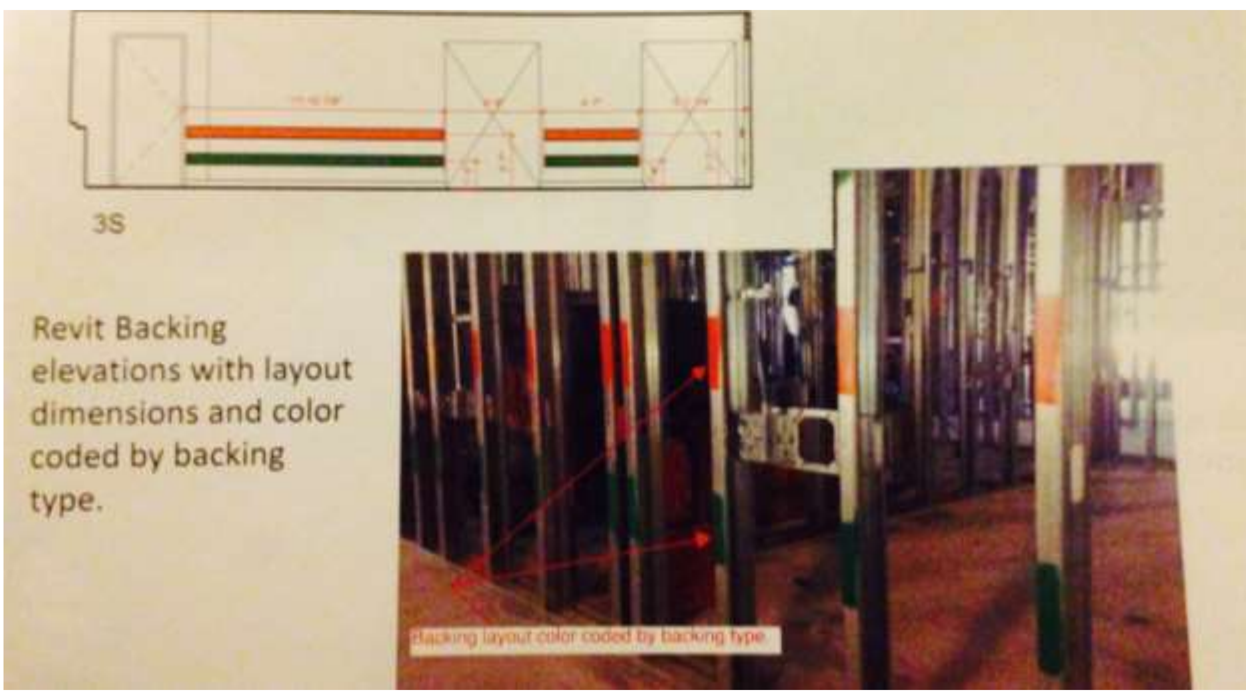


Figure 95: Backing Layout – Color Coded

Figure 96: Dry Erase Boards on All Floors

Dry erase boards were placed on every floor. These boards allow the field crew to quickly write notes and read pertinent information.

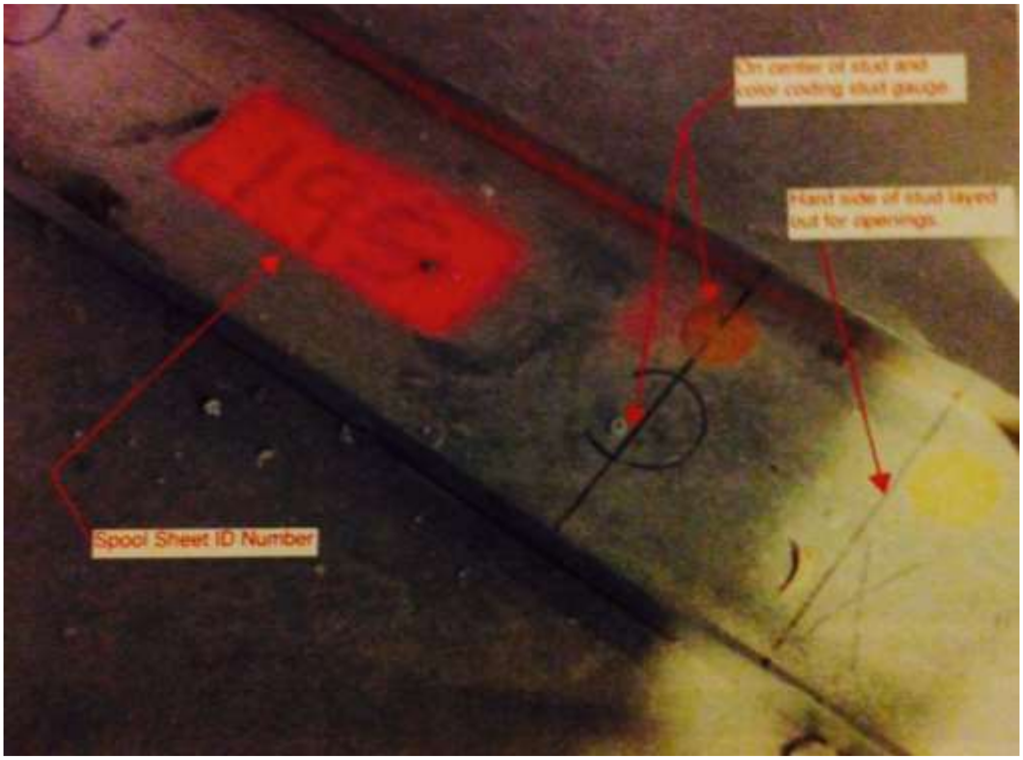


Figure 97: Spool Sheet Framing Layout

The layouts of the drywall frames are color coded and tagged. The color-coding practice (also known as poka yoke) helps reduce the number of mistakes and eliminates unnecessary measurement.

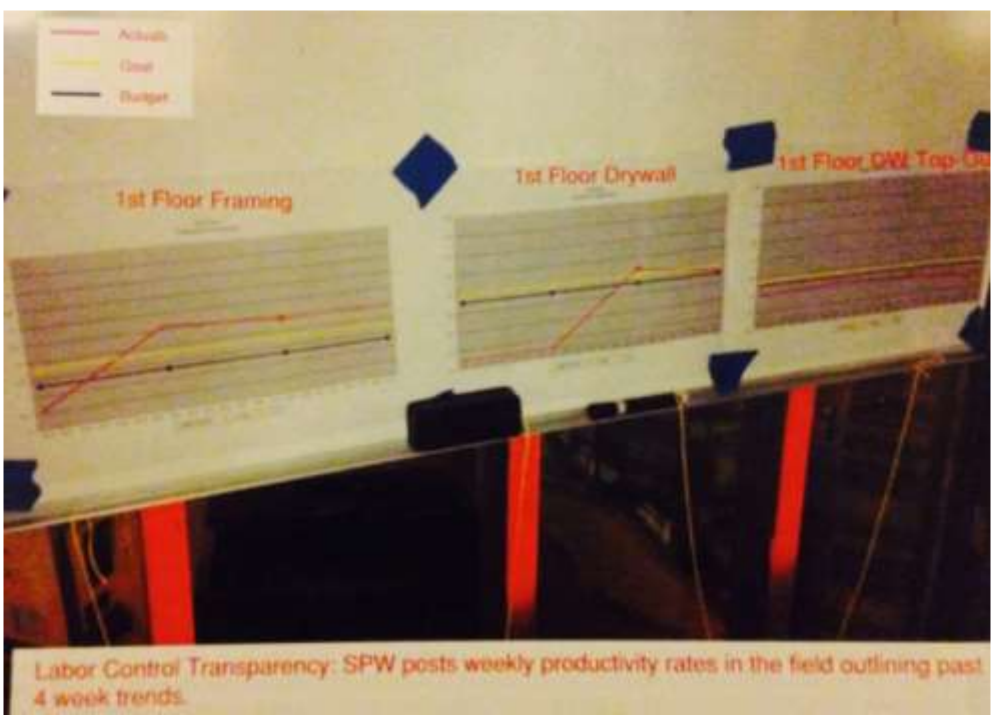


Figure 98: Labor Productivity Transparency in the Field

The labor productivity information is shown on-site for each crew. This information gave the field crew constructive feedback about their performance, promotes positive competition, and showed the field crew how their work is contributing to the project as a whole.

- General
  - Scissor lift blueprint improvement

  - Upgraded Project Inertia so that it has the ability to highlight inspection areas electronically.
  - Small batching 1st Floor more than previous planned. i.e. Area 1A and 1B in lieu of Area 1
  - Finished mock-up has been invaluable to team

- Drywall/Framing
  - Purchased cordless drywall screw guns based on worker feedback
  - Added spool sheets to kiosks and allow worker access at home.
- Mechanical/Plumbing

- Pre-program CAV controllers with battery and invertor in lieu of requiring permanent power.
- Utilize Tite-End True Torque nut in lieu of standard anchor bolt. Bolt snaps off at required torque and torque test not required.

Drywall/Framing

- Plangrid—Utilizing plangrid program to track rework and potentially use for punchlist/signoffs.
- Continuous bazooka for taping operations. Supposed to increase production by 100%

Plumbing/Sheet Metal

- Utilize inverter to test CSFD's with field staff and IOR's prior to permanent power.

General

- Utilize countdown clocks for different milestones throughout the building.
- Utilize 26 ga. sheet metal in big room so that items can be magnetized to the wall.

General

- http://www.photosynth.net
  Photosynth has the ability to take 360 degree photos with a smartphone

- Utilizing Plangrid now to perform all in-wall sign-offs. Previously we were just utilizing for punchlist/ rework. Reports have also been improved on Plangrid.

- Install sheet metal wall in Big Room.

6 Conclusion

6.1 Challenges

The application of TVD and IPD on the Temecula Valley project was not without its challenges. Some of the challenges that the team reported include:

- **Overcoming the natural tendency to design and make decisions from a silo perspective.**

“There was one or two instances where people stayed silo and eventually failed. They ended up leaving the job. “ – General Contractor

- **It is very easy to slip into old mindsets.**

“When things get tough, people have a natural tendency to revert back to the way of working that had worked for them in the past.” – Trade Partner

- **Understanding the level of accuracy that is required at certain time in the design.**

- **The team required extensive training to understand the TVD/IPD process.**

“If you are just coming from a design-bid-build [project] to a big room meeting it can be a shock.” – Trade Partner

- **Tracking production rates was very challenging.**

“Each team had their own method for tracking productivity and it took us quite a while to understand each other’s methods.” –Trade Partner

- **Developing trust within the project environment.**

- **People outside the risk pool did not want to go to the big room meeting.**

“They thought that their work was too specialized and did not think that they should go to the meeting. There was one individual, a designer, that did not continue with the project for this reason. “ – Project Manger General Contractor

- **Some people did not collaborate as well** and ended up leaving the project.

- **Contractors do not have a lot of experience with design.**

“Construction is very linear but in design you have lots of exploration of ideas. One of the things that we noticed is that contractors are used to working with finished drawings and they kept asking for us to freeze the plan. “ -Architect

- **It takes time and effort to learn other people’s workflow.** It took the team several months of training and working together to develop an understanding of each other’s work. This common understanding ultimately led to design innovations.

- **Overcoming the history of firms’ previous projects with each other.** Some people had prior working experiences with each other on some successful projects and some not so successful projects.

- **There is a tradition of “fear” of asking others to improve** (e.g. a trade partner does not want to challenge the general contractor).

6.2 Lessons Learned

The following are the lessons learned from the Temecula Valley project participants that they wish to carry with them on future projects. The information was collected from the interviews and a lessons learned presentation that the tem had put together internally.

- **Make sure that everyone attends the onboarding orientation.**

"When we had a failure from one of the trade partners and we would look back and realize that the failures came from the party that we did not include in the formal onboarding process." –General Contractor

- **TVD and IPD require commitment and investment of time and money early on in the project.**

"The start of the project is more staff intensive but what you spend upfront, you end up saving. The number of people in design is double than a traditional project. It may be difficult to convince an owner to spend as much money in pre-construction as required for an IPD/TVD project." –General Contractor

- **"The importance of 'talk before drawing' ". –** Architect

The team learned through their collaborative whiteboard sessions, that better design solutions comes from talking through the problems first with a multi-disciplinary group suggesting and testing out ideas. Only after the solution was agreed upon should the architect develop drawings.

- **"The biggest practice was the trades sharing their production rate forecasts and actual production rates weekly along with the continual improvement ideas, mutual challenges to improve, and adjustments to help each other to improve."** –Trade Partner

- **Co-location of the team throughout the design phase is dynamic in terms of the numbers of days and the specific attendees.**

There is no one size fits all for how to structure the co-location and big room meeting. At different parts in the project, different people are required and their commitments also shift depending upon the needs of the project. It is prudent to develop a co-location plan that is right for the project context.

- **"We learn to share our thoughts and unfinished work with the owner and contractor to engage them in the evolution of the design (not just a critique of it). "** –Architect

The design process became more collaborative and the iteration cycles were quicker when the architect involved the contractor, owner, and trades in developing design solutions. Rather than just relying on the contractor and trades for constructability review on a completed design, the architect was able to find much better solutions by involving the other parties from the beginning.

6.3 Processes that Led to Cost Savings

In this section, we list some of the processes that the Temecula team reported which led to cost savings on the project. These processes were reported by the Temecula Valley team through either the interviews or through the lessons learned presentation.

- **Only having to design the building once.**

"In the past, we would have to review shop drawings from the subs which is a copy of our own drawings. Every time that you pass the baton, there is a probability that you can drop it." -Architect

- **Reduce over designing and over communicating in documents, reducing batch sizes of design products, and reducing unnecessary tolerances of the design.**

“You don’t have to specify all the criteria [in the design documents] because the person that you need to communicate with is there in the same room. Over specifying is a safety measure that we used [on more traditional projects] to protect ourselves. We also reduced the batch size of our design work. For example, we did not need to have the [whole] floor plan done all at once; we just need to complete the portion that is necessary for the next step. We can have different groups working on individual rooms. Parallelizing the working and making smaller batches allows the design work to proceed much quicker.” -Architect

- **Significant savings resulted from pooling resources and purchasing in bulk.**

“When we looked at the trade’s bids, many trades budgeted money for the same stuff. You don’t have to buy it seven times if you identify it early. Instead it is better to just buy it once for the whole project and share. Items such as: fork truck, scissors lift, cleaning, insulation, fire stopping, caulking were shared on this project. In terms of materials, when we bulk order them, we could get a cheaper price.” –General Contractor

- **Taking a closer examination of how people do work.**

“Having carts together so that people do not have to walk to get their tools, packaging and labeling materials, and putting everything on wheels [improved the efficiency] ”. – Trade Partner

- **A continual search for opportunities for prefabrication.**

“The exterior wall was prefabricated in major panels and brought up. The more work that you can do off-site, the more savings that you have in your labor rate in the field. On future projects, we plan on prefabricating the restrooms.” –General Contractor

- **Elimination of change orders and RFIs.**

“I learned that there is so much knowledge from the subs and contractors that we can benefit from. IPD in a co-location environment was a huge benefit. If you had a question about clearance for a structural element, you have the structural engineering, MEP, and estimator to really give you the data to make decisions.” -Architect

- **More rigorous analysis of the owner’s business case and value added components.**

“There is a lot of waste in healthcare where a lot of things are overdone when they do not add value to the owner’s business case. Corridors, hallways, and anything that takes up room in the building that is not functional is essentially waste. On Temecula, we designed a single corridor that is double loaded. In our concept we were able to reduce the corridor space by 30%. Certain spaces have common functionality but are used at different times and by different departments. We looked for ways to reduce duplicates. The client demanded that there be no departmental boundaries [in the operations department]. We also talked a lot designing the building to support the operations. “ - Architect

- **Money was able to move between boundaries.**

“The fire sprinklers cost half a million dollars more but made the project progress better in other areas. This led to an overall cost savings” –Trade Partner

“We spend some extra money building the garage doors between the patient rooms. The garage doors had no impact on the final usage of the building but gave us greater efficiency during construction because our scissor lifts, materials, and equipment could be more easily moved in after the drywall framing was already erected." –General Contractor

- **Understanding everyone's perspective instead of just passing the blame.**

"We are better informed and ready to make corrections. No one is sitting around pointing fingers. Since we are all there together, we cannot assign fault. It is a great experience when people want to find the best solution rather than point fingers. " –Architect

- **Slowing down in order to speed up.**

"We can now wait longer before committing to a specific design because we now have a better team. " -Architect

- **"Swarming" around problems.**

"We were able to found cross-functional teams to quickly fix problems as they arise. Since we all share in pains and gains of the project, we did what was right for the project. We did not have to go through a lengthy RFI/Change Order process before addressing a problem." -Trade Partner

- **Problem solving and documenting design alternatives with A3s.**

"The A3s were great because it allowed us to document all of our ideas in one place. After doing several A3s, I realize that the results from the process is almost always different than my initial idea. By going through the [structured] process, I was able come up with more thoughtful solutions." – General Contractor

- **Using A3s and Choosing by Advantages to make sound and transparent decisions.**

"CBA helped us make more informed decisions. The method allows us to engage with the owner and ask for their inputs." – Architect

- **Design in "sets" and narrowing the sets based on looking at the whole of the project**, including price and schedule, and narrowing at the last responsible moment – not rushing to make decisions early-on.

- **Co-location of an integrated team that included the key trades.**

"The trade partner's involvement was key in the TVD process. They had so much valuable knowledge to contribute to the design". - Architect

- **Measuring productivity and openly sharing forecasts and actual rates weekly.**

- **The use of "plus/deltas" and rigorous efforts to eliminate repeat deltas.**

- **Periodic "reflections" using "start, stop, and continue".**

- **Increased level of trust between parties who are usually adversarial.**

"Many of the members on this project have worked together on projects in the past. Some of those projects turned out well and some of those projects resulted in adversarial relationships. The ability to overcome the adversarial past and build trust was key to our success as a team." - Architect

- **We focused on delivering the project rather than on our own companies.**

"The shared risk and reward meant that we were going to be successful only if the project was successful. This made people focus on doing what is best for the project rather than what is best for their own team (e.g., moving scope of work to the parties who is able to do it the cheapest)." – General Contractor

- **Improved quality of life of the individuals** – had time for fun (golf, ping pong etc.), did not feel pressure to work 14-hour days.

" The processes that we used gave us much better control over the project as a whole. As a result, we spent less time fire fighting problems which made the work environment less stressful." – General Contractor

6.4 Areas for Improvement

The following are some areas for improvement from the Temecula Valley project participants that they wish to carry with them on future projects.

- **Better communication of the business case and the Target Cost to the team.**

Several of the project participants within the risk pool reported that they did not know the owner's business case and how the Target Cost was set. In the future, the team should spend time during the onboarding process to educate members about the business case. The team should know how and why their cost saving innovations relate to the business case. The target cost of the project needs to be grounded on the owner's allowable cost in the business case, otherwise the practice of setting a cost target can be construed as arbitrary and exploitative.

- **Keep better notes from big room and coordination meetings.**

One project participant reported that many good ideas were presented at coordination meeting but were not incorporated into the project. Perhaps having a dedicated person record the ideas presented at the big room and following up with the implementation can allow more ideas to be fully realized. One suggestion is to de-couple the person who raises an idea from the person who has to champion it. The team may benefit from more idea generation if people who do not feel the pressure of doing more work after they have raised an idea. After an idea is raised, if it is valid, the best person to carry the idea forward should take it. This person may or may not be the person who raised the idea in the first place.

- **Apply BIM at the right time.**

"On this project we brought some trade partners too early and try to have them model when not enough of the design was completed. We wasted money by starting the BIM process too early. " – General Contractor

At the time of the application of this project, BIM technology had not yet matured. There are still many opportunities to improve on the coordination, model-based estimating, etc. Determining the acceptable level of detail and what needs to be modeled was a challenge on this project and future implementation and research may help resolve this problem.

- **Research better ways to manage BIM tolerances.**

Tolerances management for the BIM model was reported as one of the trouble areas for the project.

- **Motivate and incentivize members outside the risk pool to be as engaged as members inside the risk pool.**

There were several instances where members outside the risk pool did not attend the coordination or big room meetings. One way to rectify this issue is to explicitly state that attending the coordination meetings is mandatory. Lump Sum contractors should be informed of this requirement and include it in their bid.

6.5 Updating the P2SL Current Process Benchmark on Target Value Design

Every case study project is examined for practices and methods that can be incorporated into a revised TVD Benchmark. The following features of the Temecula Valley Hospital project will be examined for incorporation:

- Modeling and simulation of healthcare operations
- On-boarding process
- Co-designing process
- Shared governance; including the joint pay application process involving all risk pool member companies
- Steering to Targets in Construction; including First Run Studies and tracking profitability

6.6 Acknowledgments

The P2SL TVD Research Group would like to thank the participants of the Universal Health Services (UHS) Temecula Valley project for taking time out of their busy schedule to share information and the lessons learned from this project. From UHS, Bill Seed and Tara Laski have been invaluable resources of information and knowledge. Steve Wilson from HMC Architects, Tom McCready from DPR Construction, Brent Nikolin from Turner Construction, Ken Lindsey from Southland Industries, Kristin Hill from Inside Out Consulting, and George Vangelatos from HMC Architects provided data and reviewed the report.

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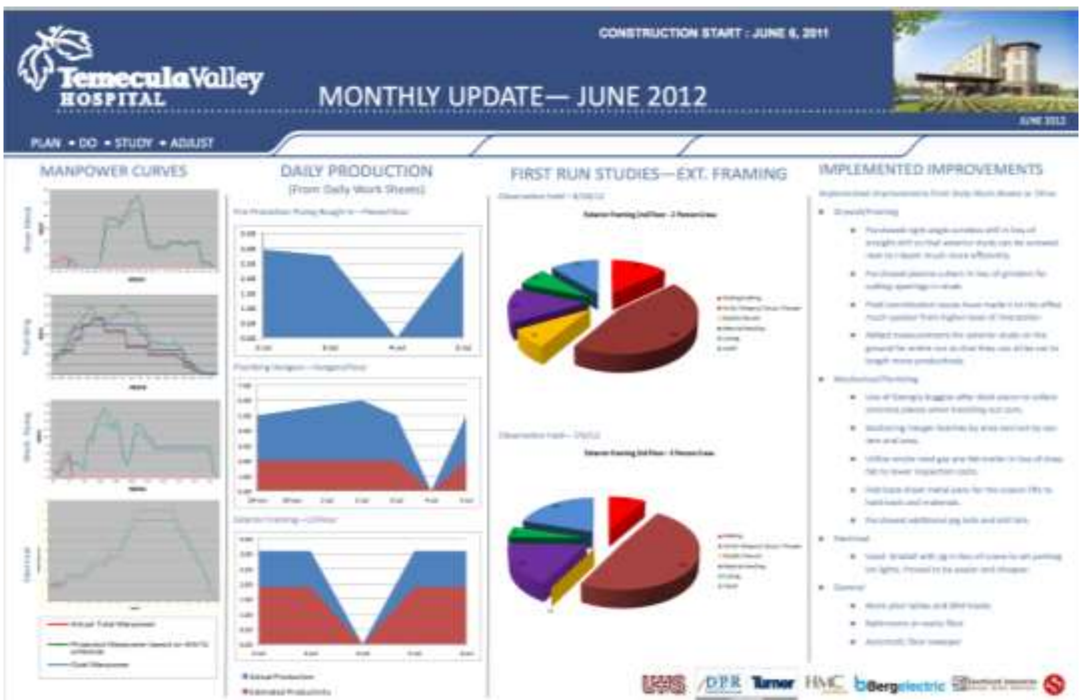
8 Appendices[15]

8.1 Monthly A3 Status Updates

8.1.1 June 2012

[15] All appendix files are available at: www.targetvaluedesign.org.



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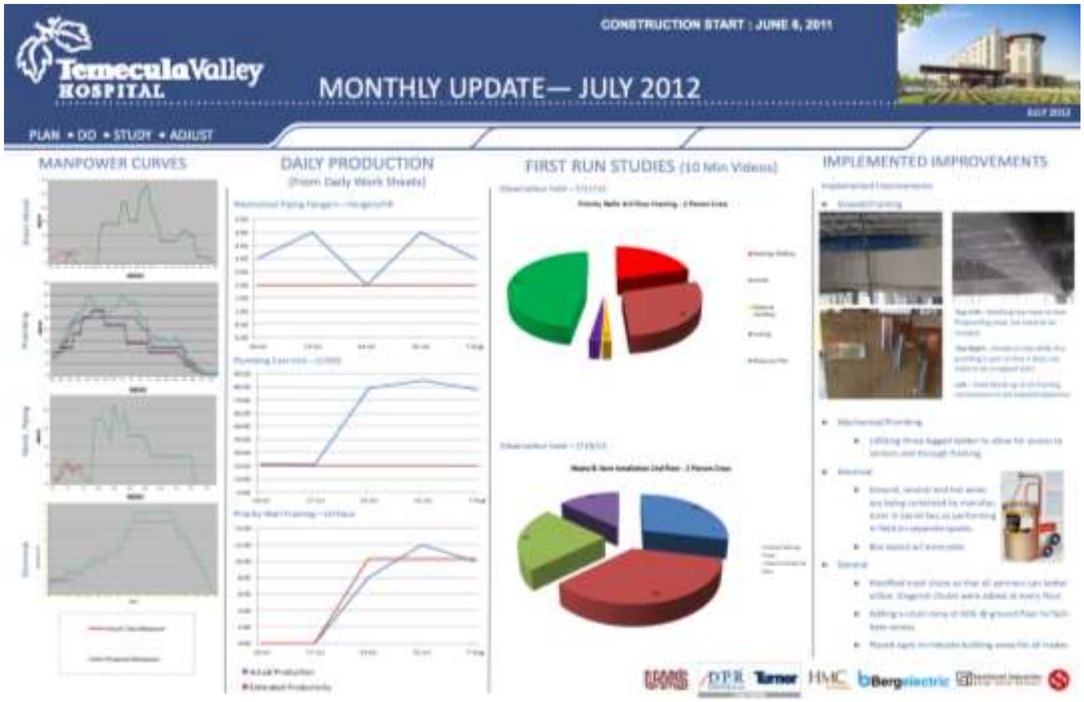
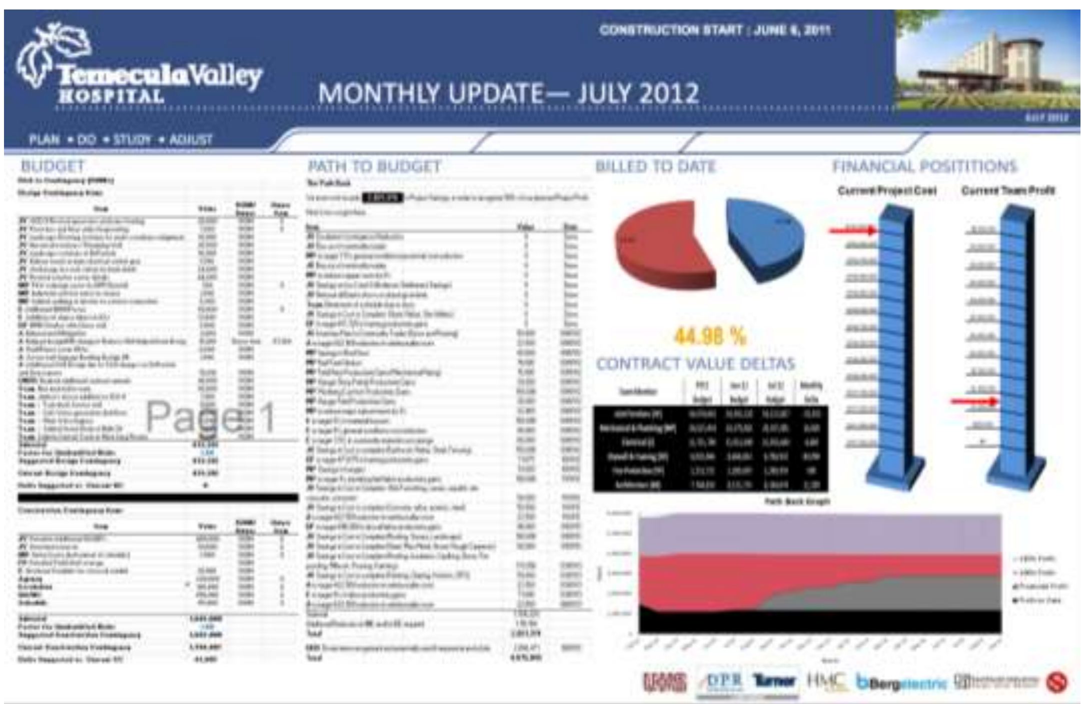
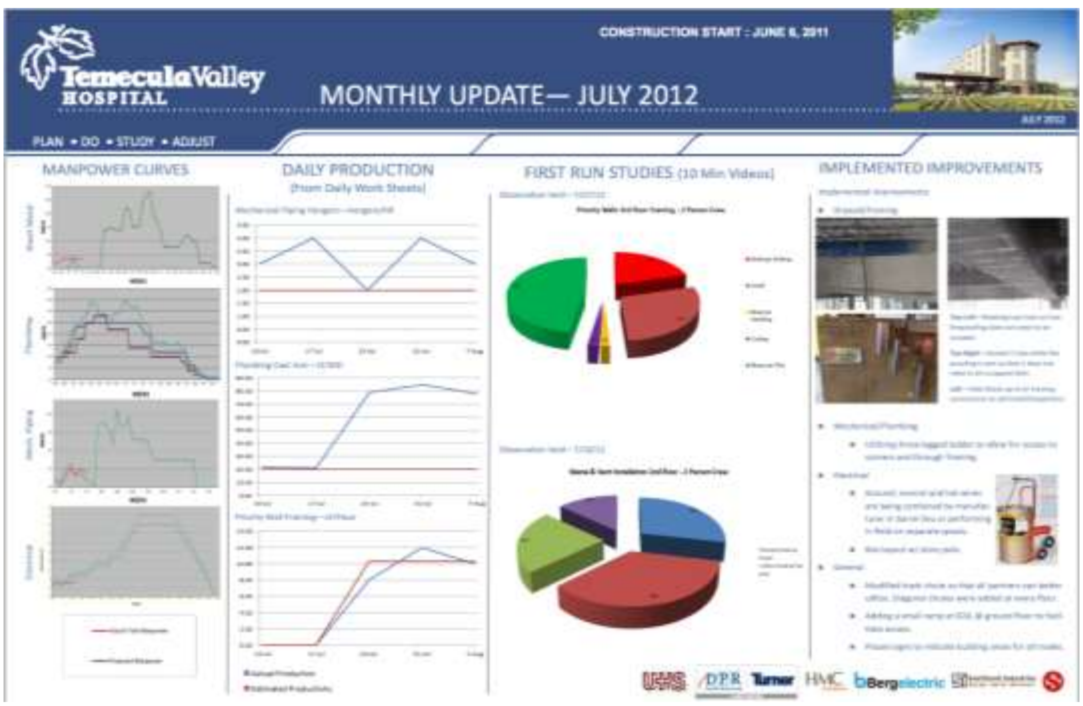


CONSTRUCTION START : JUNE 6, 2011
TemeculaValley HOSPITAL
MONTHLY UPDATE— JULY 2012
PLAN • DO • STUDY • ADJUST
MANPOWER CURVES
DAILY PRODUCTION
(From Daily Work Sheets)
FIRST RUN STUDIES (10 Min Videos)
IMPLEMENTED IMPROVEMENTS
DPR
Turner
HMC
Bergelectric



CONSTRUCTION START : JUNE 6, 2011
TemeculaValley HOSPITAL
MONTHLY UPDATE— JULY 2012
PLAN • DO • STUDY • ADJUST
BUDGET
PATH TO BUDGET
BILLED TO DATE
FINANCIAL POSITITIONS
Current Project Cost
Current Team Profit
44.98 %
CONTRACT VALUE DELTAS
Page 1
DPR
Turner
HMC
Bergelectric



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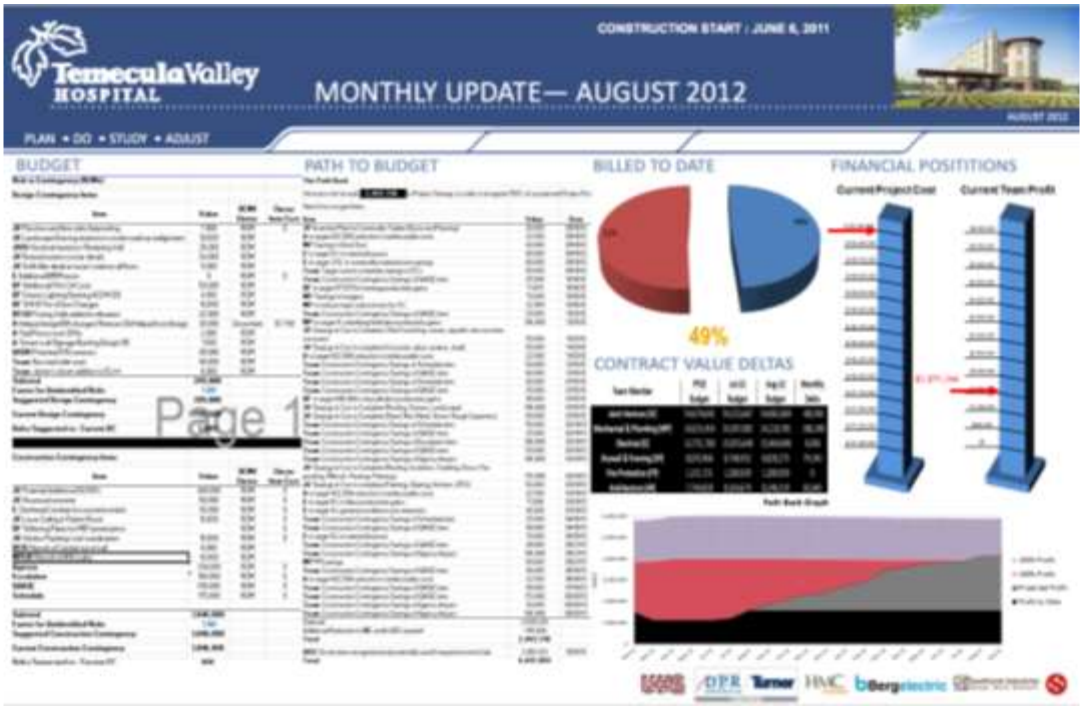
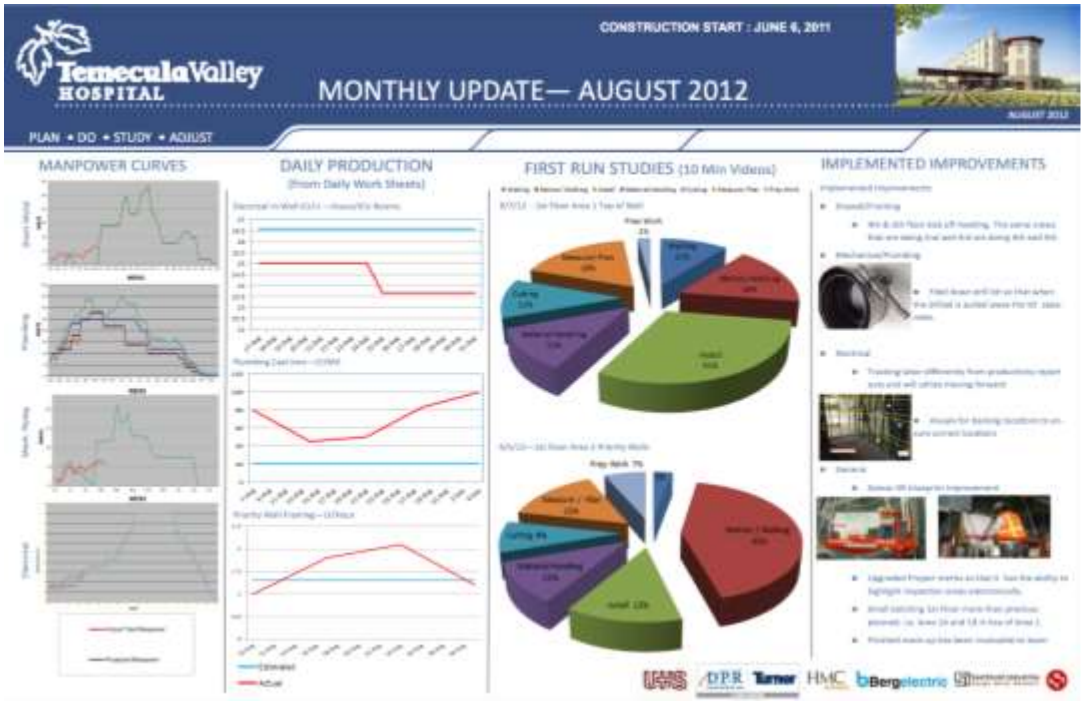

CONSTRUCTION START : JUNE 6, 2011
Temecula Valley
HOSPITAL
MONTHLY UPDATE— AUGUST 2012
PLAN • DO • STUDY • ADJUST
BUDGET
PATH TO BUDGET
BILLED TO DATE
FINANCIAL POSITITIONS
49%
CONTRACT VALUE DELTAS
Page 1
DPR
Turner
HMC


CONSTRUCTION START : JUNE 6, 2011
Temecula Valley
HOSPITAL
MONTHLY UPDATE— AUGUST 2012
PLAN • DO • STUDY • ADJUST
SAFETY LOG
INSPECTIONS
SCHEDULE & MILESTONES
ORIGINAL SCHEDULE
PPC vs. Baseline Schedule Variance
APPROVED SCHEDULE (W/ ESA EXTENSION)
CURRENT SCHEDULE
PHOTOS
LESSONS LEARNED/INNOVATIONS/GOOD 5 WHY
DPR
Turner
HMC



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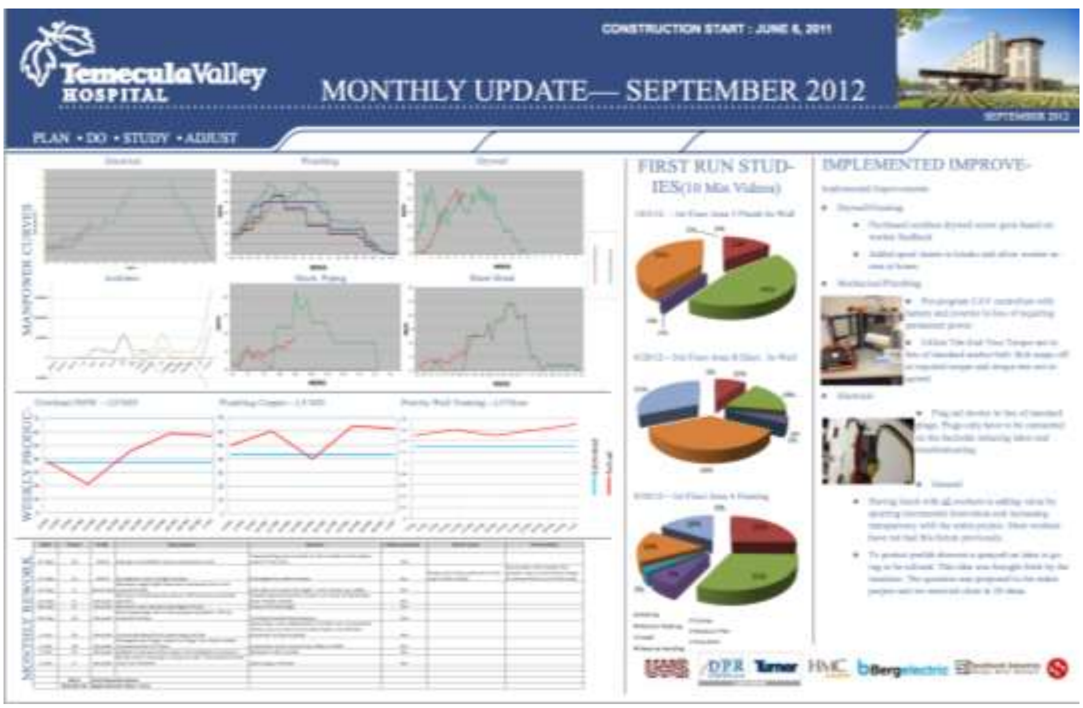
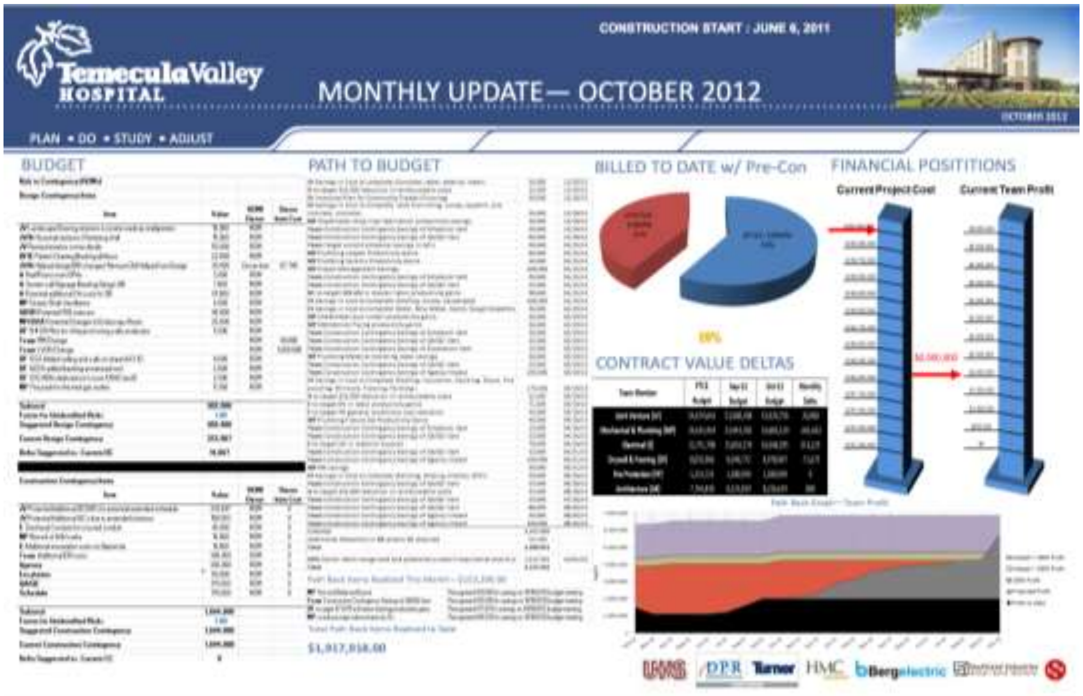


8.1.5 October 2012


CONSTRUCTION START : JUNE 6, 2011
Temecula Valley
HOSPITAL
MONTHLY UPDATE— OCTOBER 2012
PLAN • DO • STUDY • ADJUST
VIDEO STUDIES
(10 Min Videos)
IMPLEMENTED IMPROVEMENTS


CONSTRUCTION START : JUNE 6, 2011
Temecula Valley
HOSPITAL
MONTHLY UPDATE— OCTOBER 2012
PLAN • DO • STUDY • ADJUST
SAFETY LOG
INSPECTIONS
SCHEDULE & MILESTONES
ORIGINAL SCHEDULE
PPC vs. Baseline Schedule Variance
APPROVED SCHEDULE (W/ ESA EXTENSION)
CURRENT SCHEDULE
PHOTOS
LESSONS LEARNED/A3/GOOD 5 WHY



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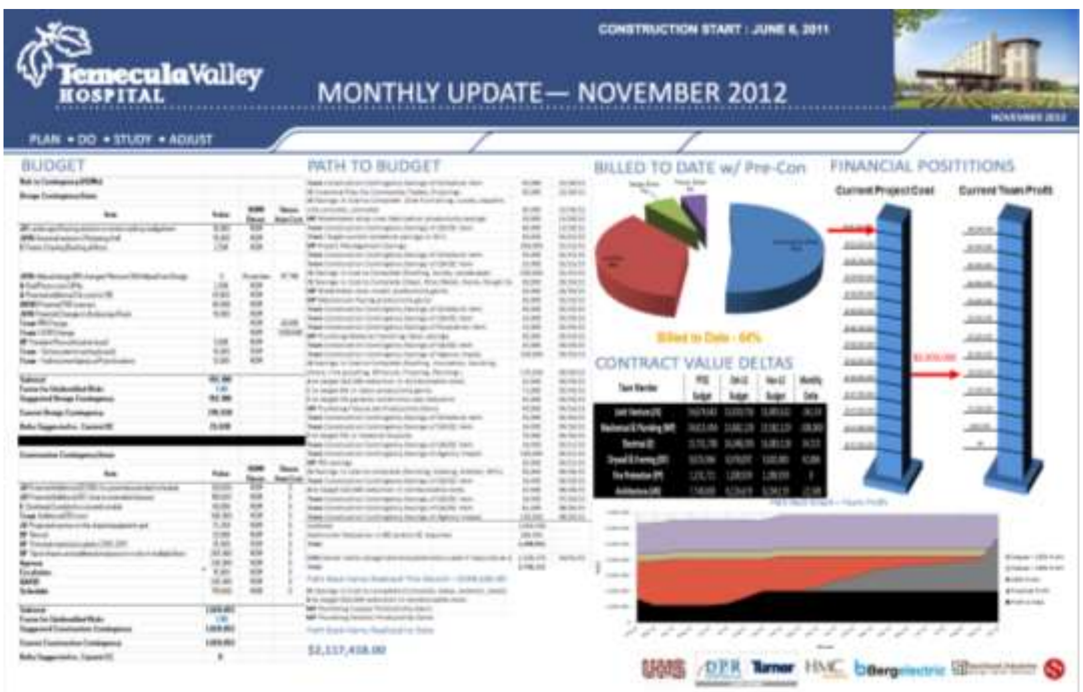

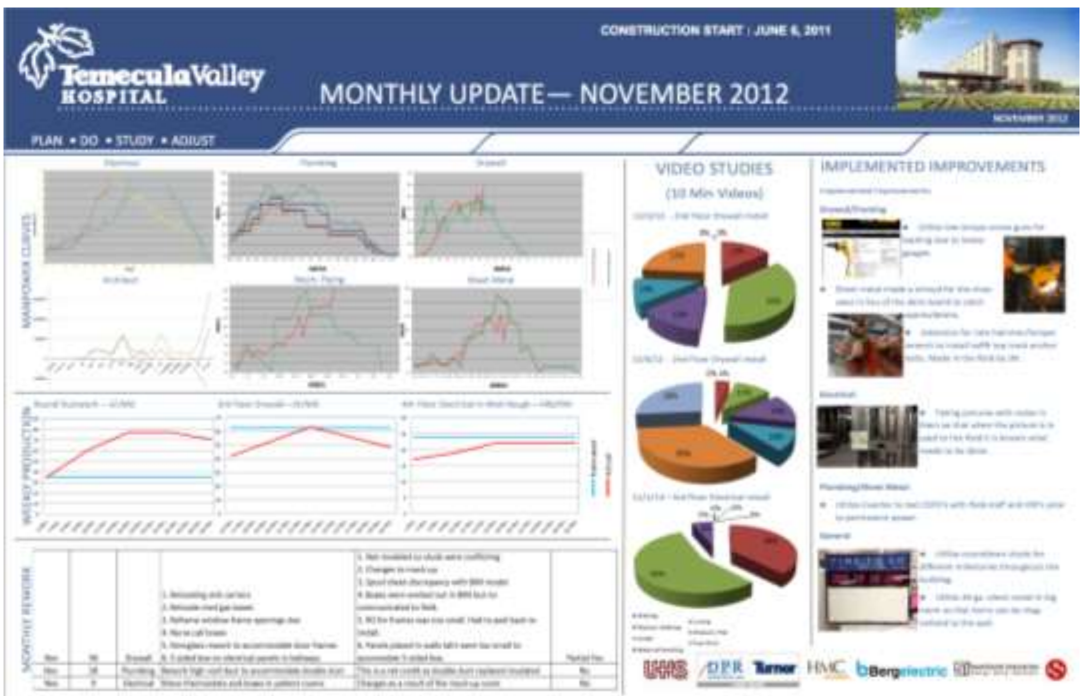

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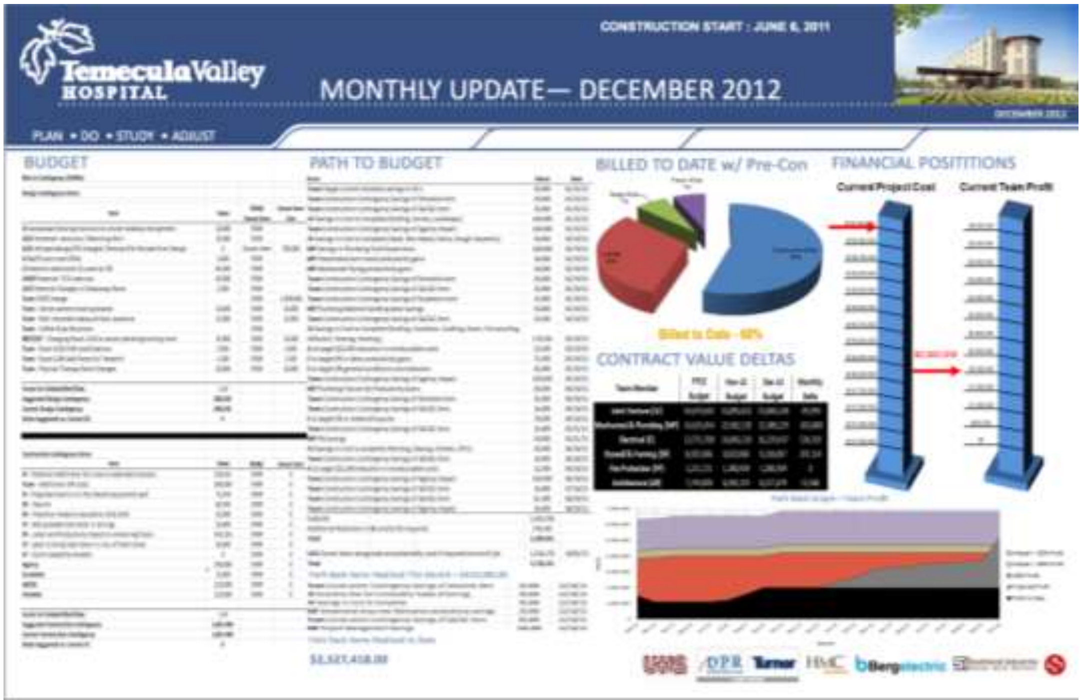
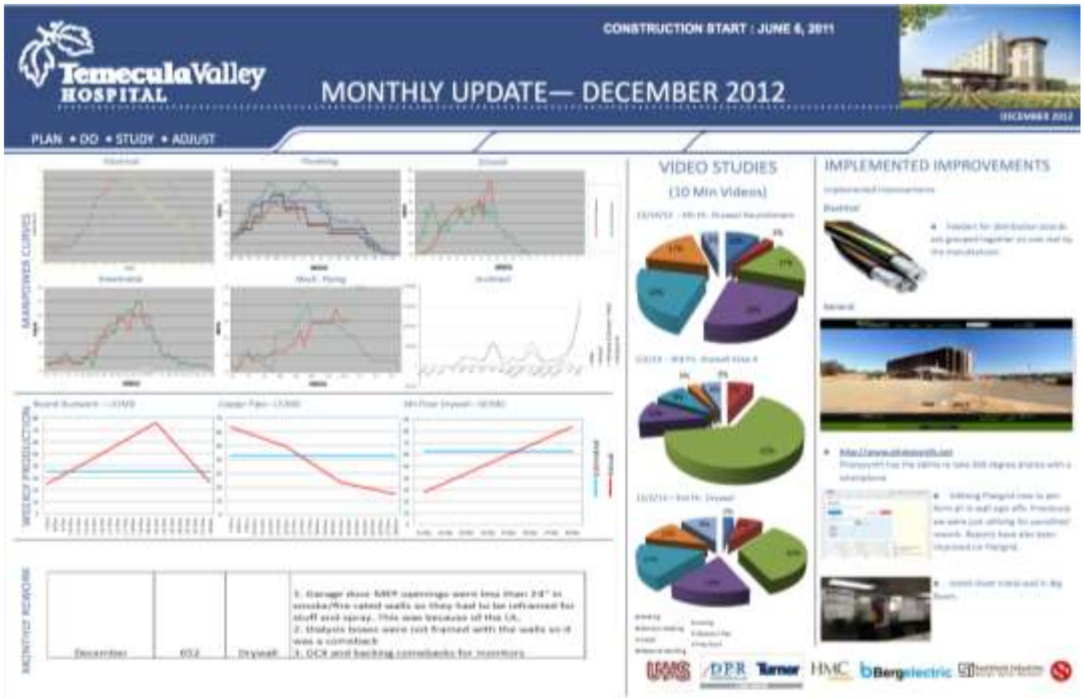

CONSTRUCTION START : JUNE 6, 2011
Temecula Valley
HOSPITAL
MONTHLY UPDATE— DECEMBER 2012
PLAN • DO • STUDY • ADJUST
BUDGET
PATH TO BUDGET
BILLED TO DATE w/ Pre-Con
FINANCIAL POSITITIONS
Current Project Cost
Current Team Profit
CONTRACT VALUE DELTAS
DPR
Turner
HMC
Bergelectric


CONSTRUCTION START : JUNE 6, 2011
Temecula Valley
HOSPITAL
MONTHLY UPDATE— DECEMBER 2012
PLAN • DO • STUDY • ADJUST
SAFETY LOG
INSPECTIONS
SCHEDULE & MILESTONES
PPC vs. Baseline Schedule Variance
PHOTOS
LESSONS LEARNED/A3/GOOD 5 WHY
DPR
Turner
HMC
Bergelectric



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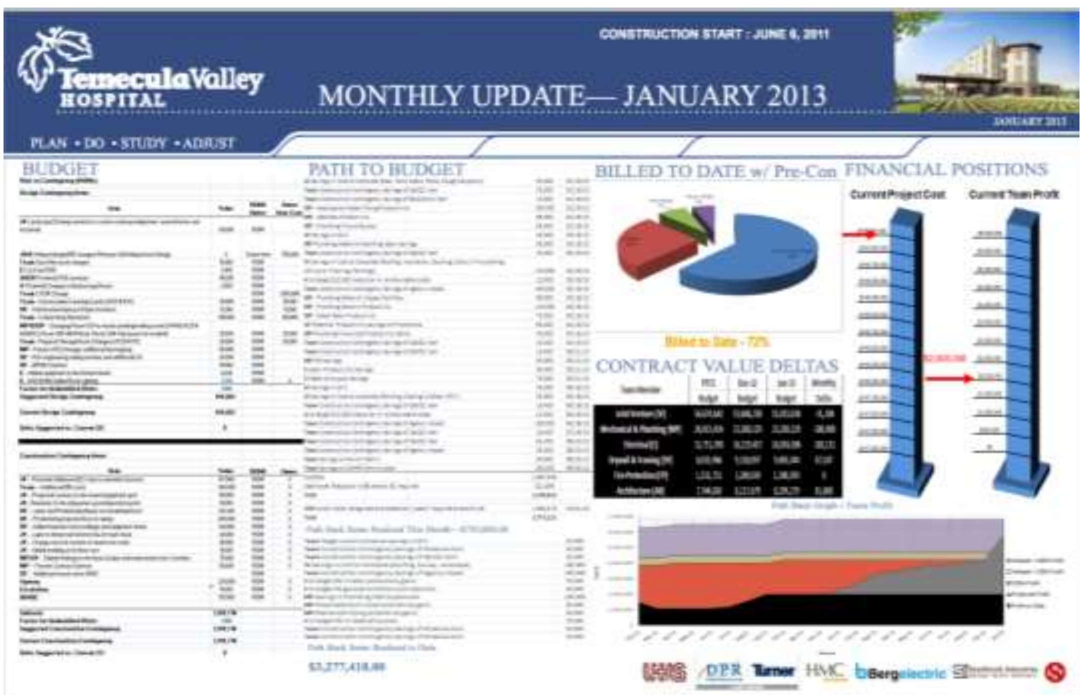

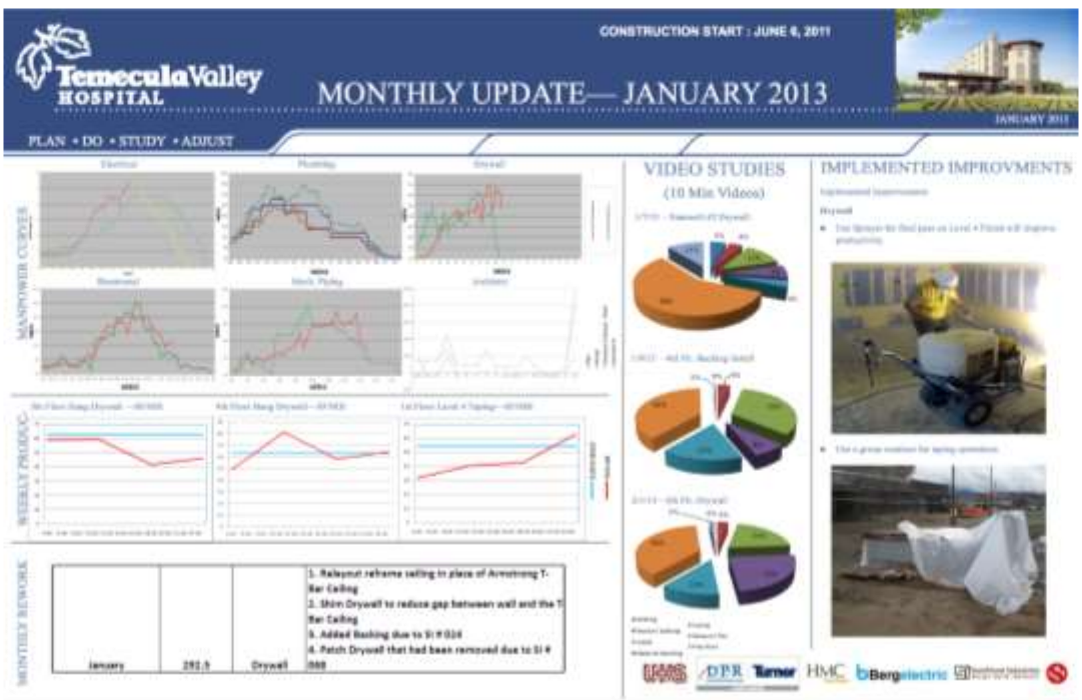

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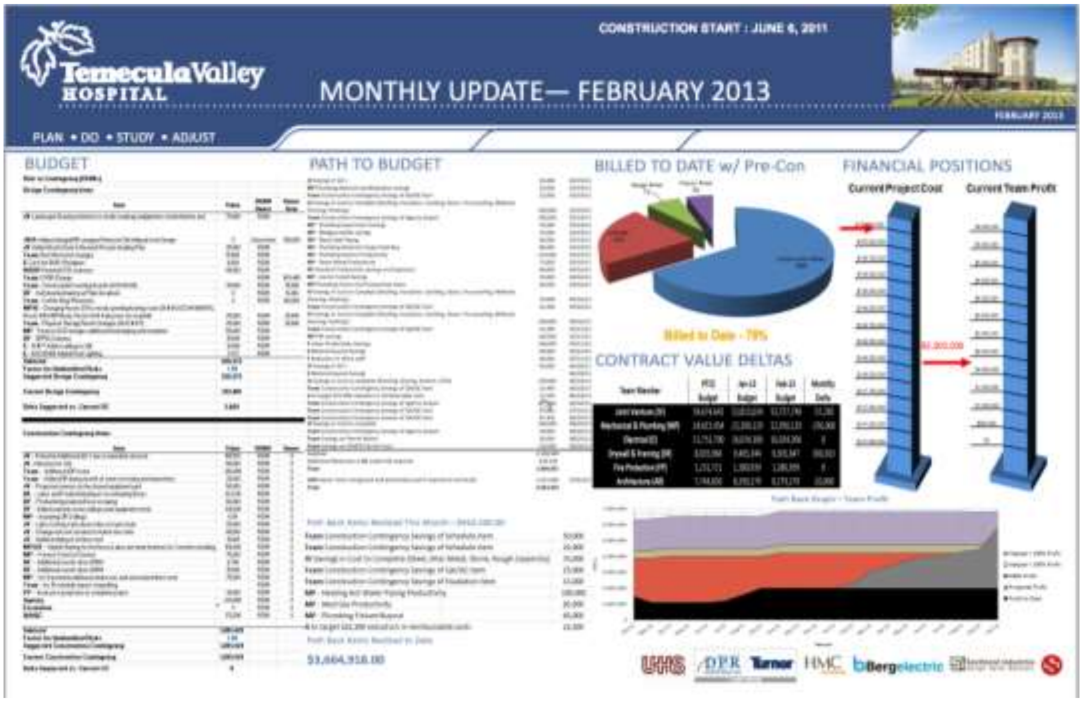
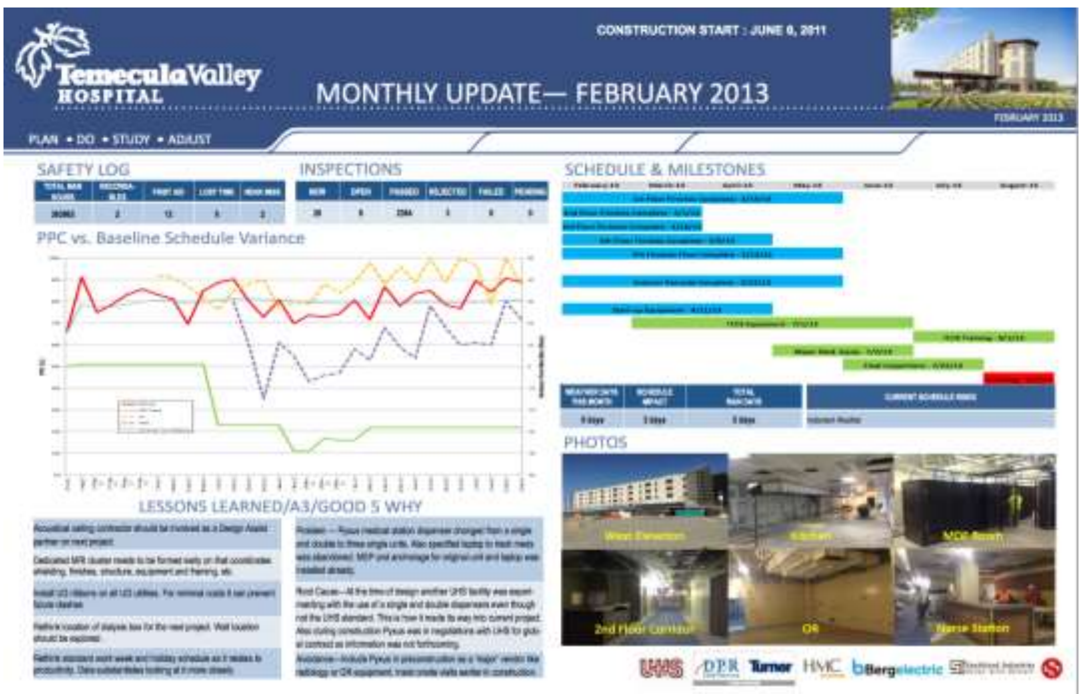
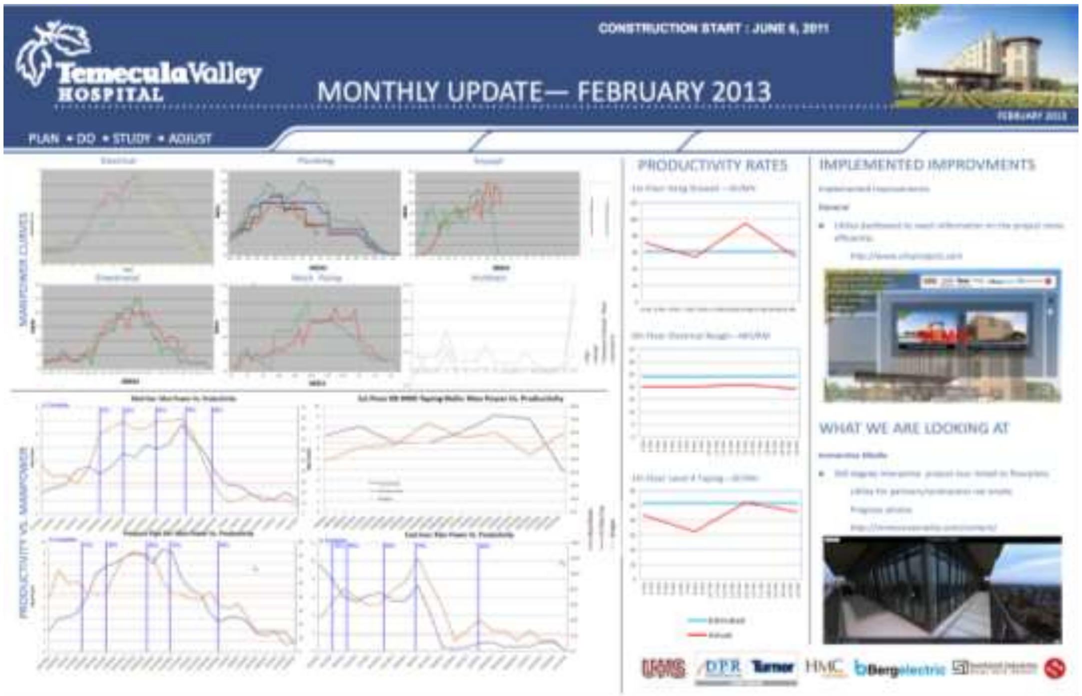

CONSTRUCTION START : JUNE 6, 2011
Temecula Valley
HOSPITAL
MONTHLY UPDATE— FEBRUARY 2013
PLAN • DO • STUDY • ADJUST
BUDGET
PATH TO BUDGET
BILLED TO DATE w/ Pre-Con
FINANCIAL POSITIONS
Current Project Cost
Current Team Profit
Billed to Date - 79%
CONTRACT VALUE DELTAS
UHS
DPR
Turner
HMC
Bergelectric


CONSTRUCTION START : JUNE 6, 2011
Temecula Valley
HOSPITAL
MONTHLY UPDATE— FEBRUARY 2013
PLAN • DO • STUDY • ADJUST
SAFETY LOG
INSPECTIONS
SCHEDULE & MILESTONES
PPC vs. Baseline Schedule Variance
PHOTOS
West Elevation
Kitchen
2nd Floor Corridor
OR
Nurse Station
LESSONS LEARNED/A3/GOOD 5 WHY
UHS
DPR
Turner
HMC
Bergelectric



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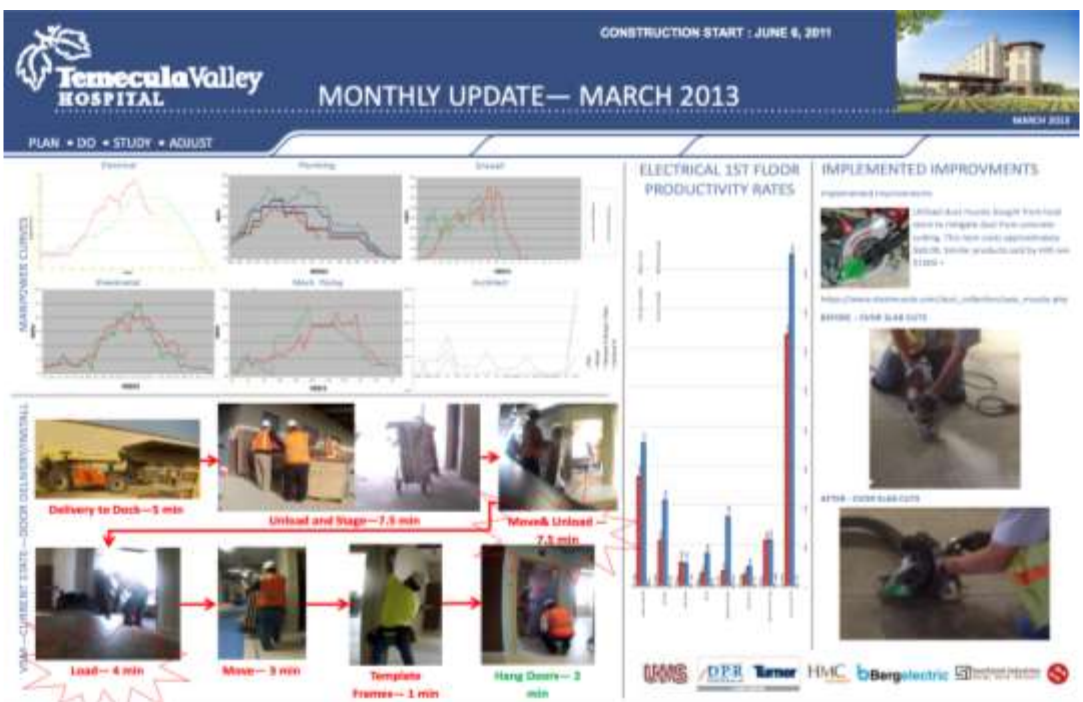

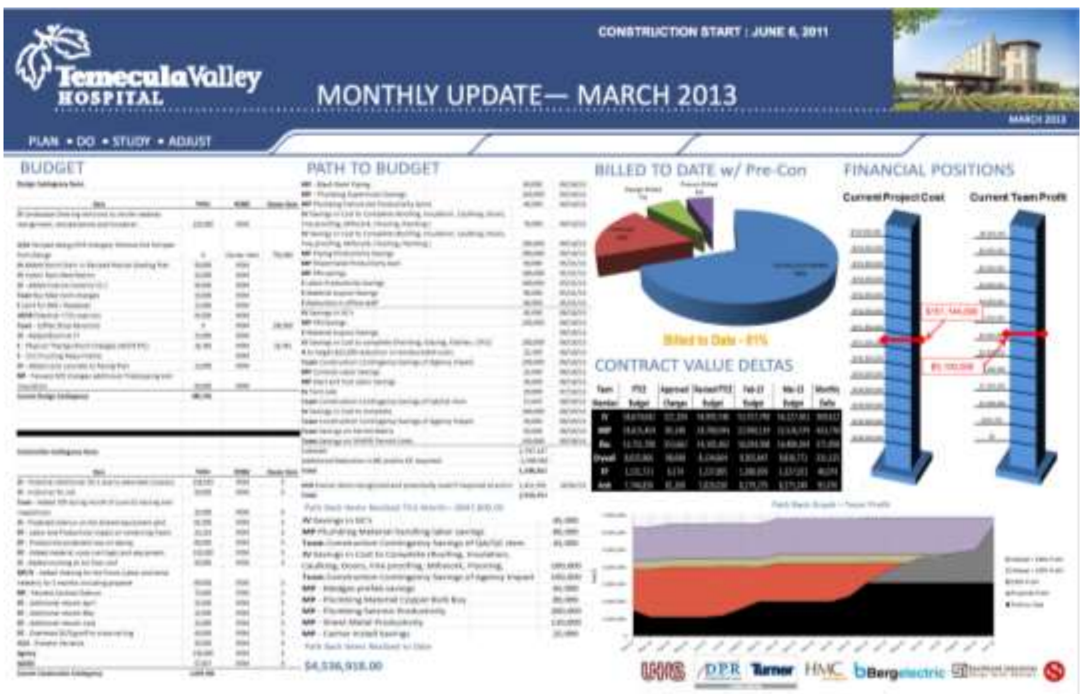

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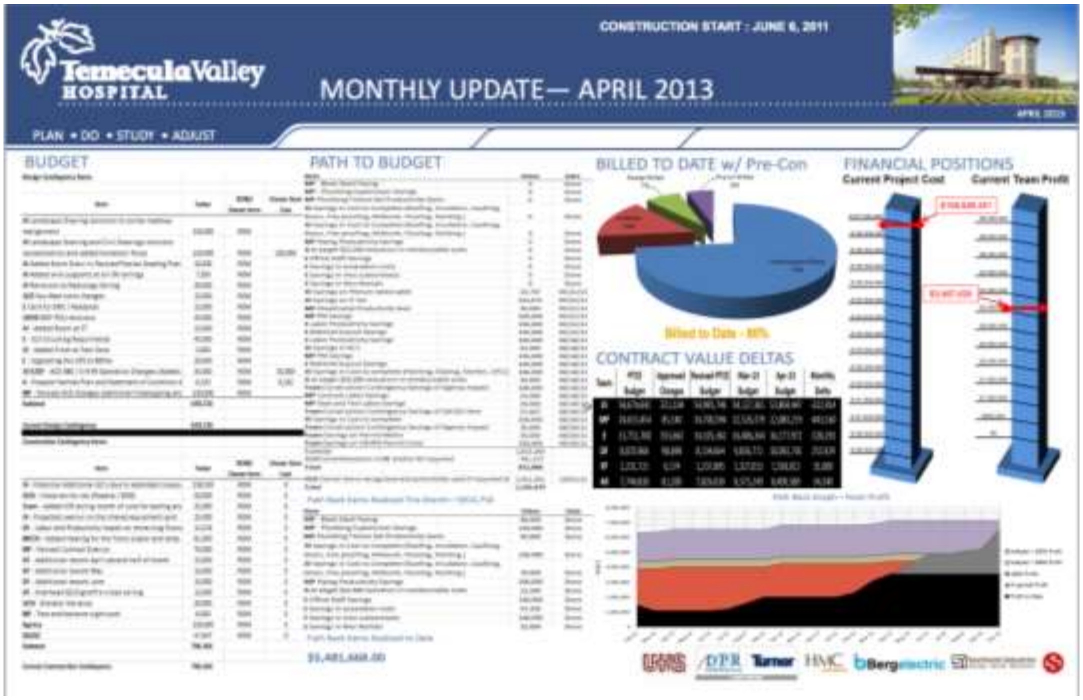
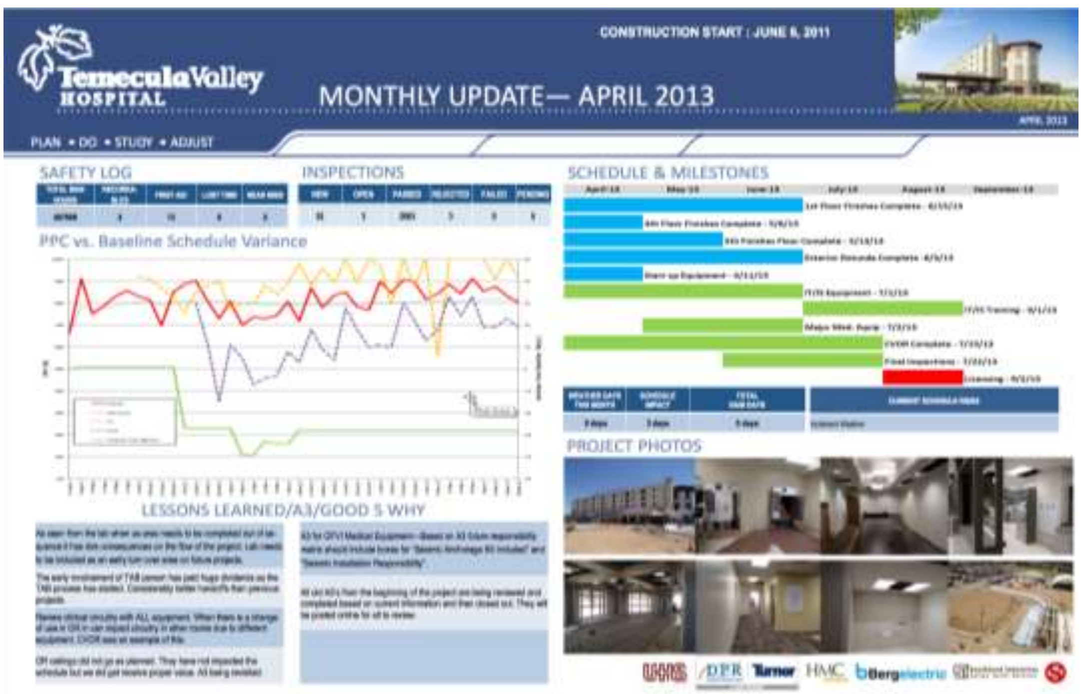
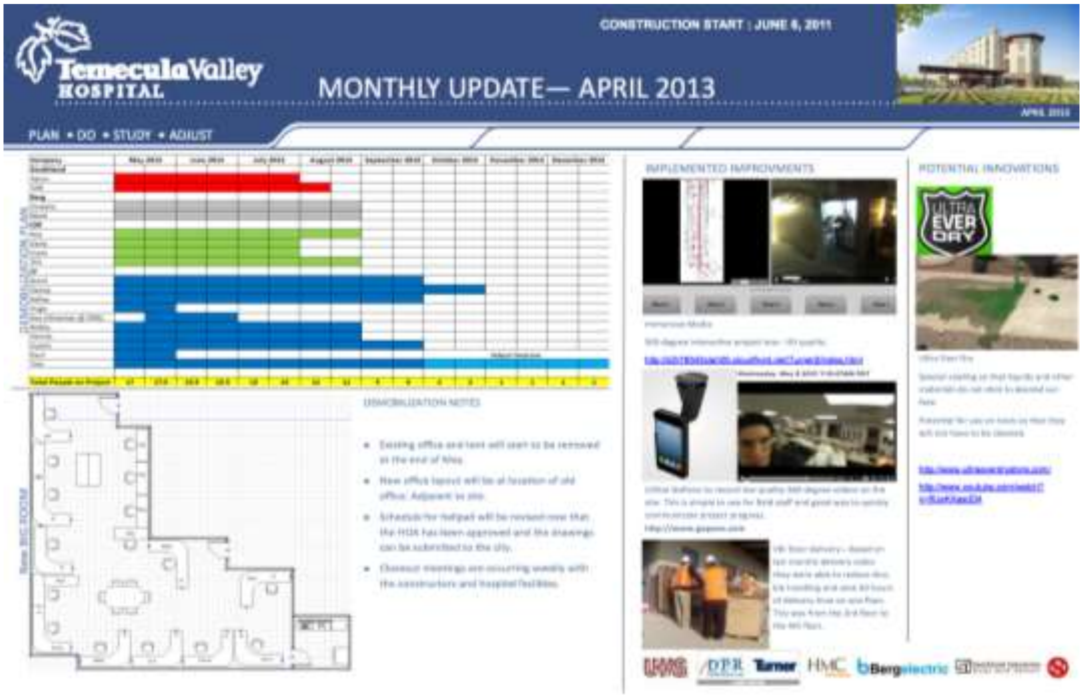

CONSTRUCTION START : JUNE 6, 2011
Temecula Valley
HOSPITAL
MONTHLY UPDATE— APRIL 2013
PLAN • DO • STUDY • ADJUST
BUDGET
PATH TO BUDGET
BILLED TO DATE w/ Pre-Con
FINANCIAL POSITIONS
Current Project Cost
Current Team Profit
CONTRACT VALUE DELTAS


CONSTRUCTION START : JUNE 6, 2011
Temecula Valley
HOSPITAL
MONTHLY UPDATE— APRIL 2013
PLAN • DO • STUDY • ADJUST
SAFETY LOG
INSPECTIONS
SCHEDULE & MILESTONES
PPC vs. Baseline Schedule Variance
LESSONS LEARNED/A3/GOOD 5 WHY
PROJECT PHOTOS



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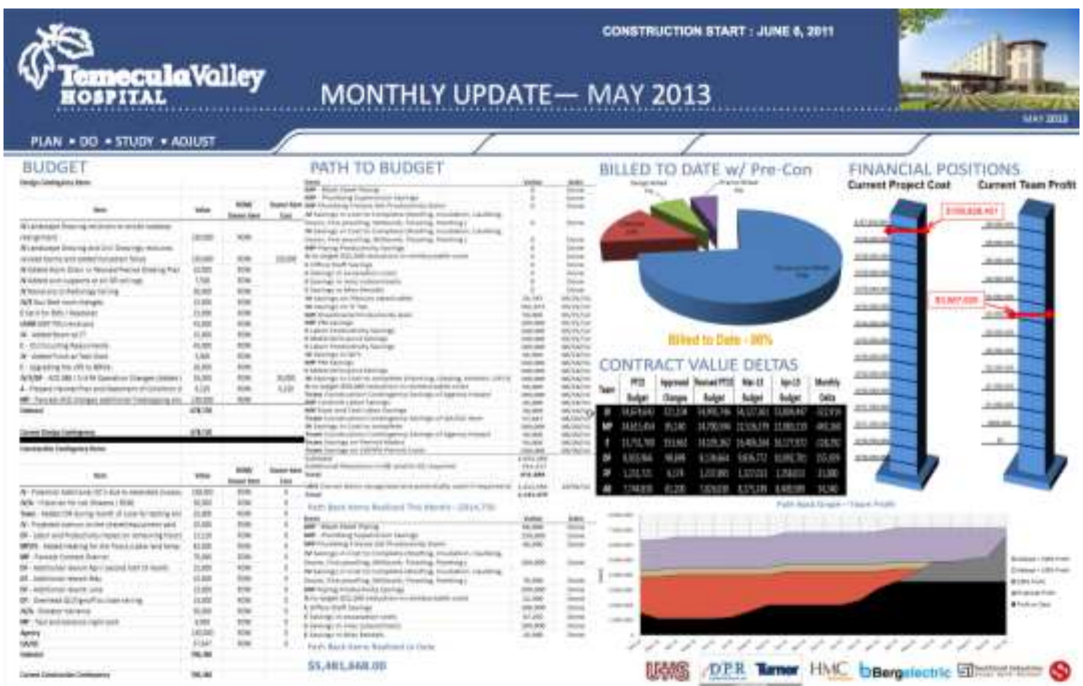

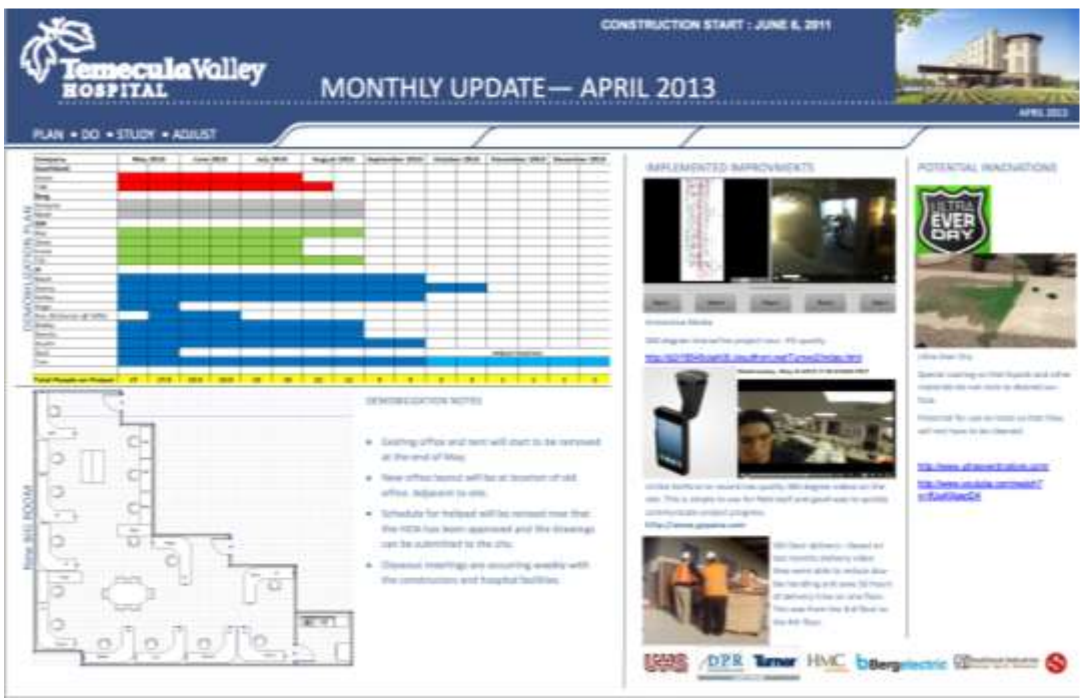

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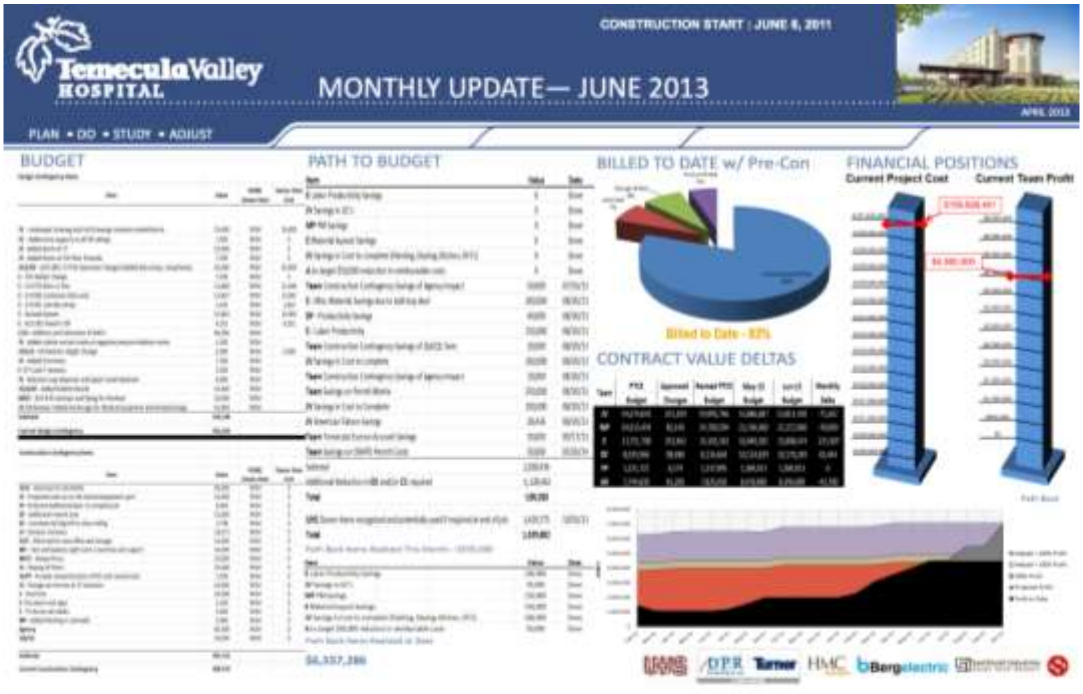

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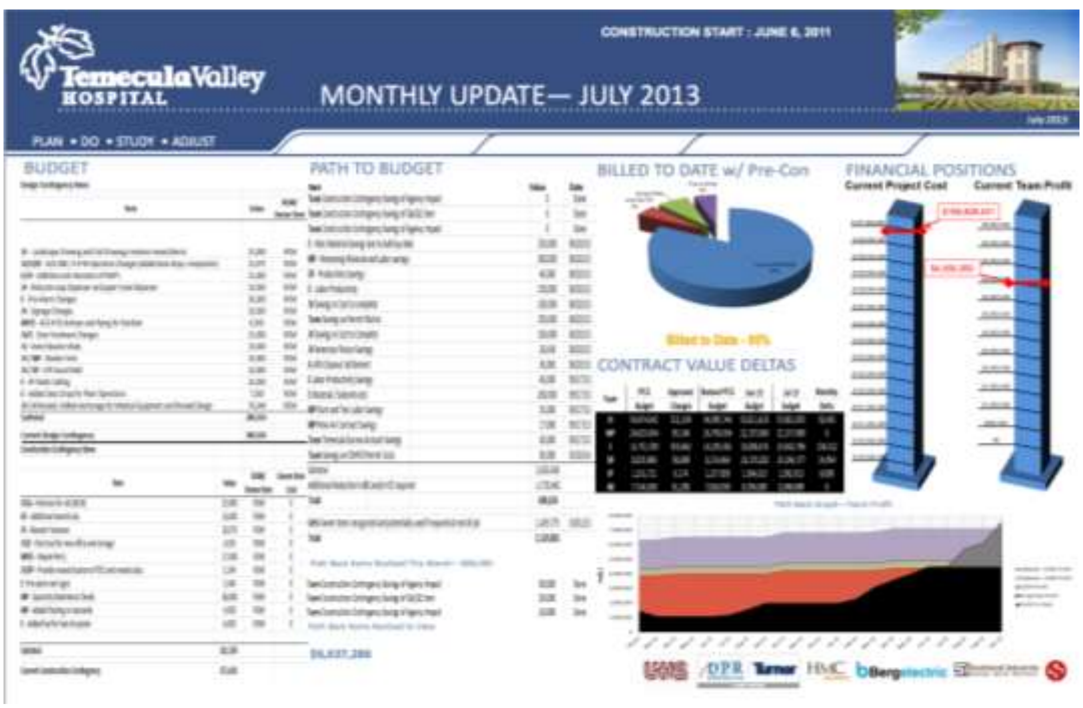

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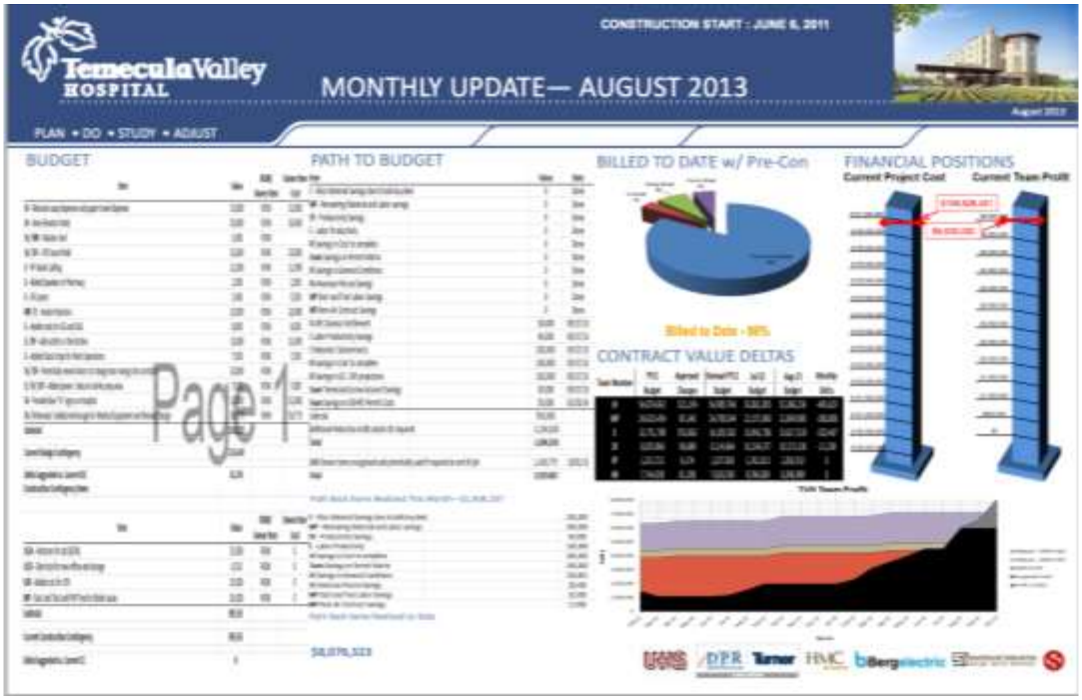

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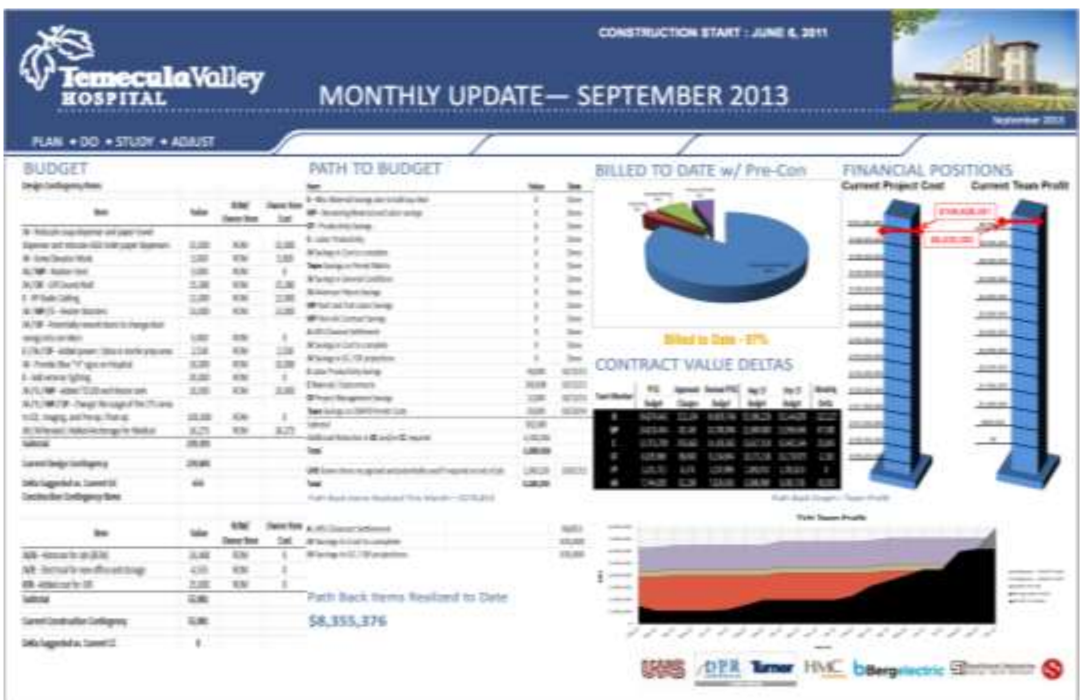

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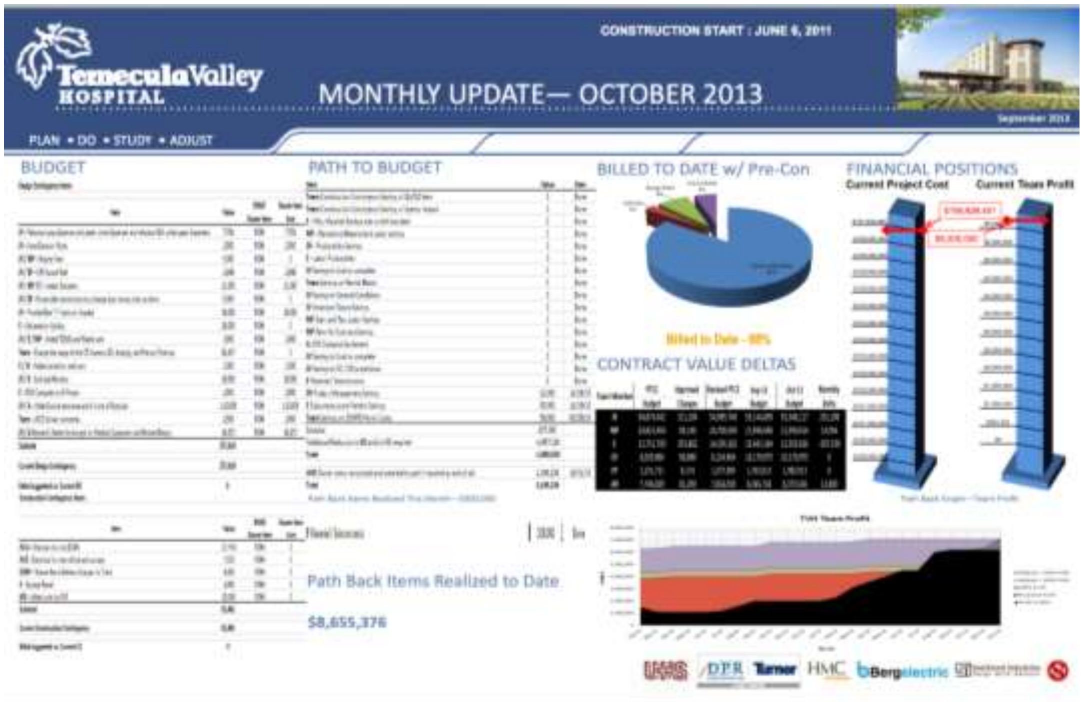

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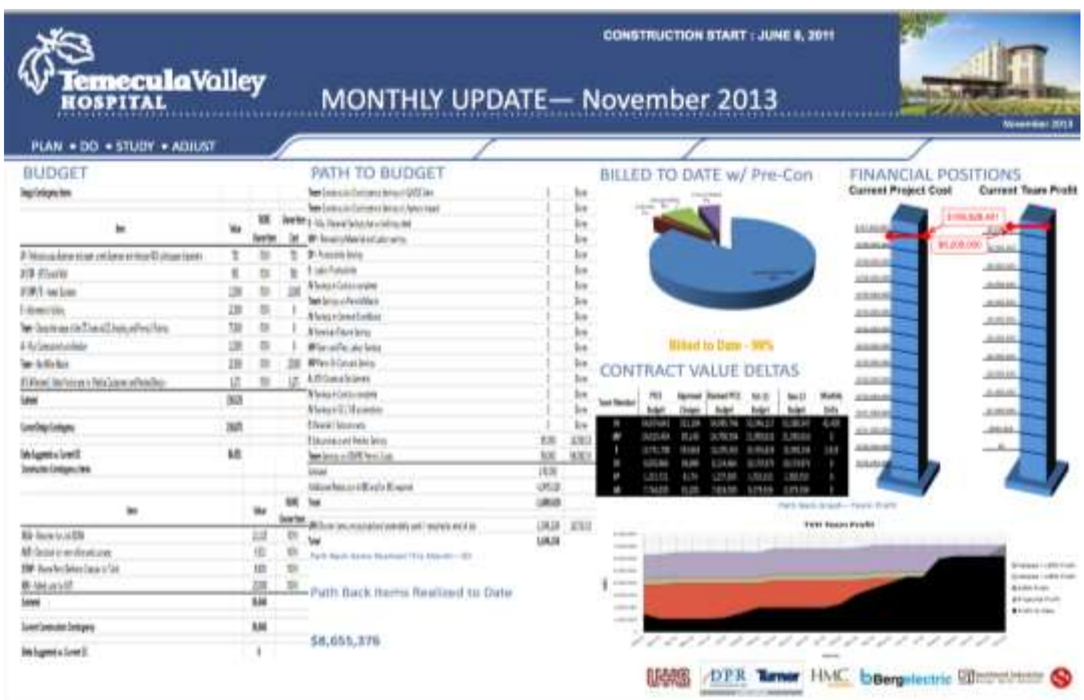
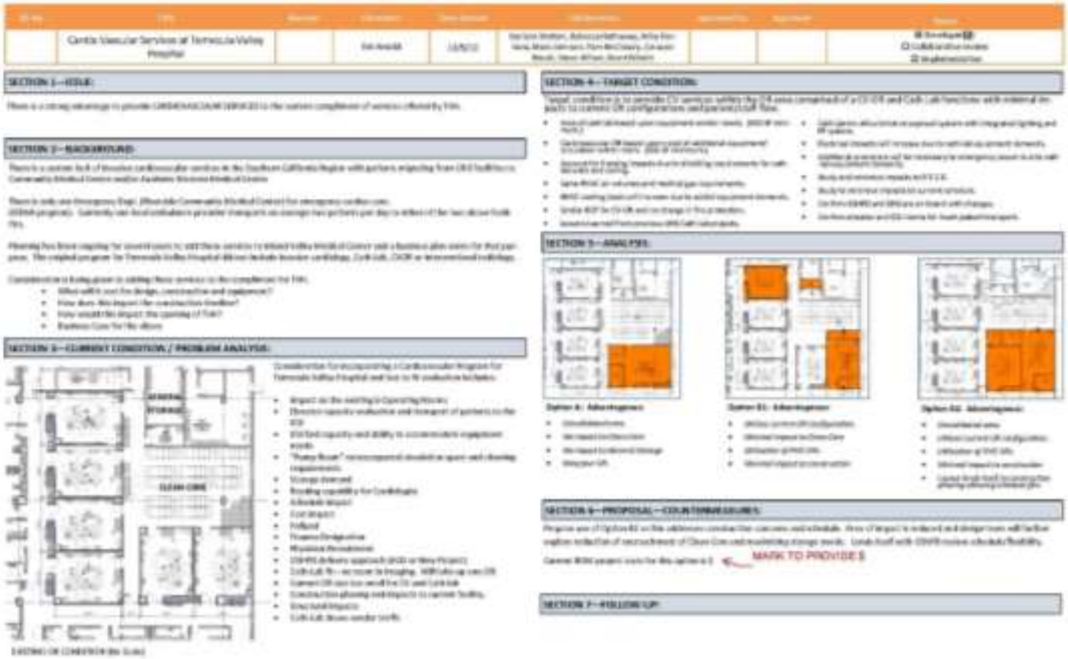


8.1.19 December 2013

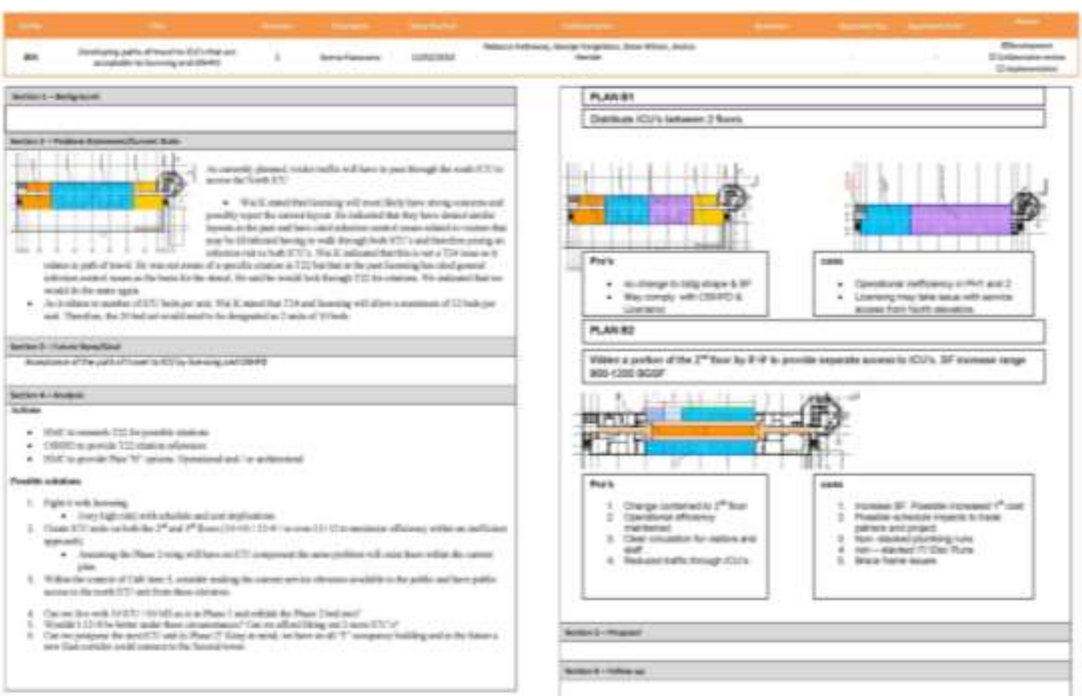

CONSTRUCTION START : JUNE 6, 2011
Temecula Valley
HOSPITAL
MONTHLY UPDATE— December 2013
PLAN • DO • STUDY • ADJUST
BUDGET
PATH TO BUDGET
BILLED TO DATE w/ Pre-Con
FINANCIAL POSITIONS
Current Project Cost
Current Team Profit
CONTRACT VALUE DELTAS
Path Back Items Realized to Date
DPR
Turner
Berg electric

8.2 Sample A3 Documents

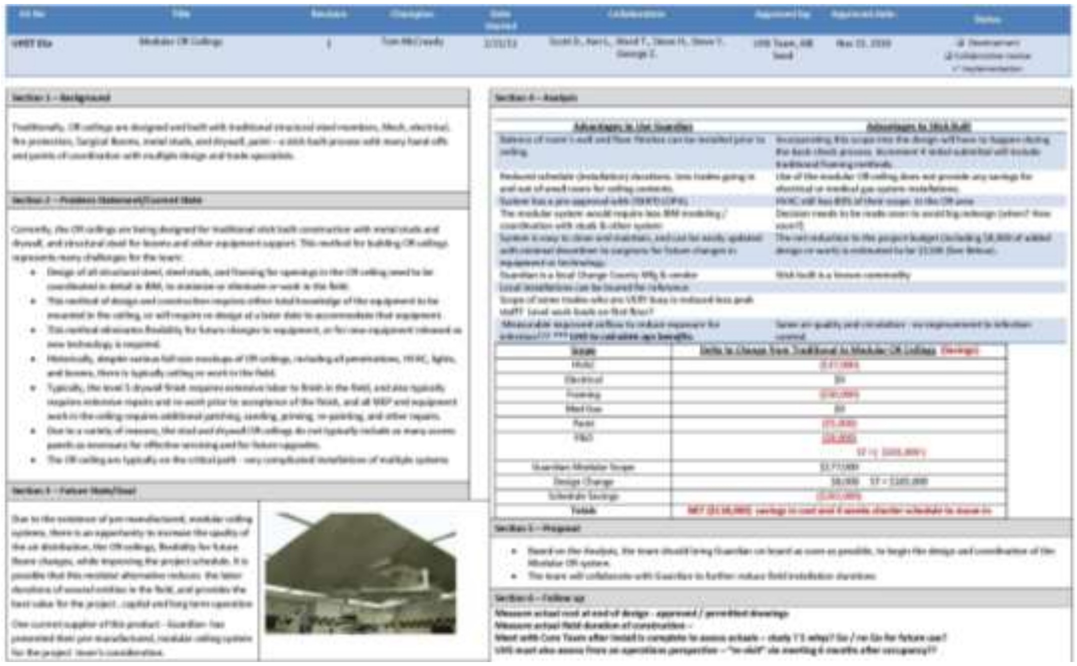
8.2.1 Cardio Vascular Services at Temecula Valley



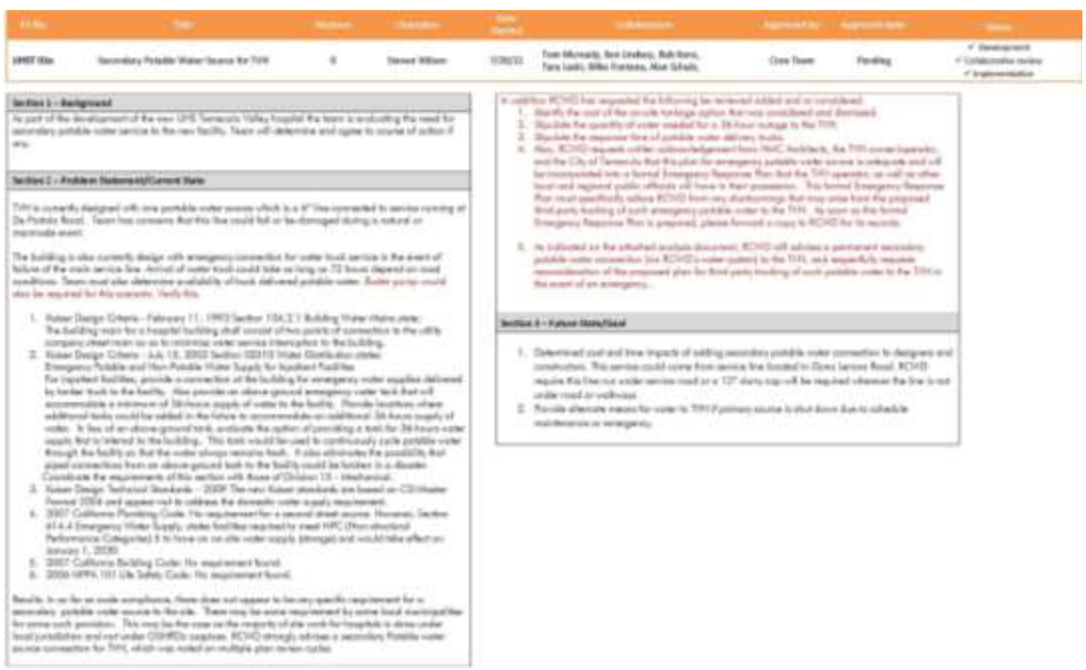
8.2.2 Developing Paths of Travel to ICUs that are Acceptable to Licensing and OSHPD



8.2.3 Modular OR Ceilings

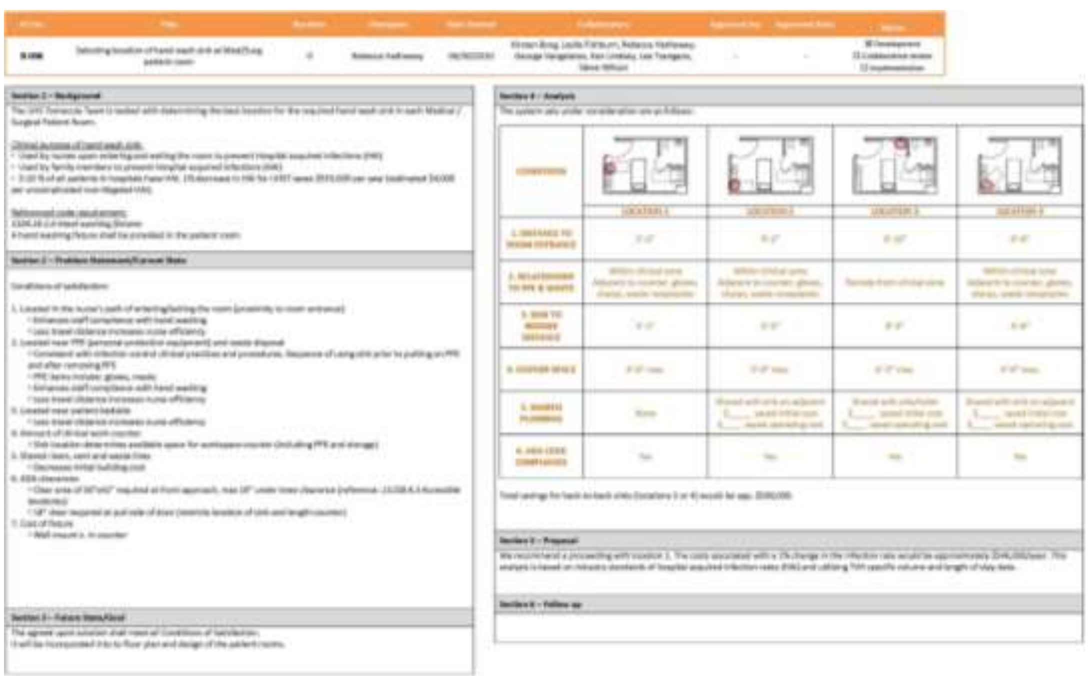


8.2.4 Secondary Portable Water Source for TVH

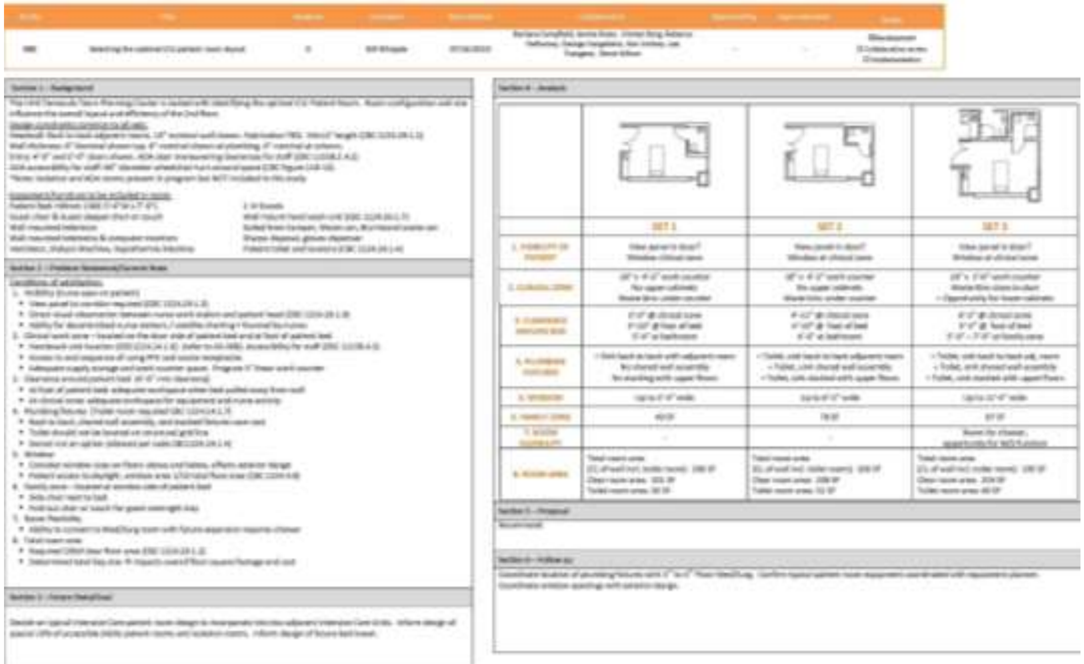


8.2.5 Select the Supply Chain Methodology for TVH

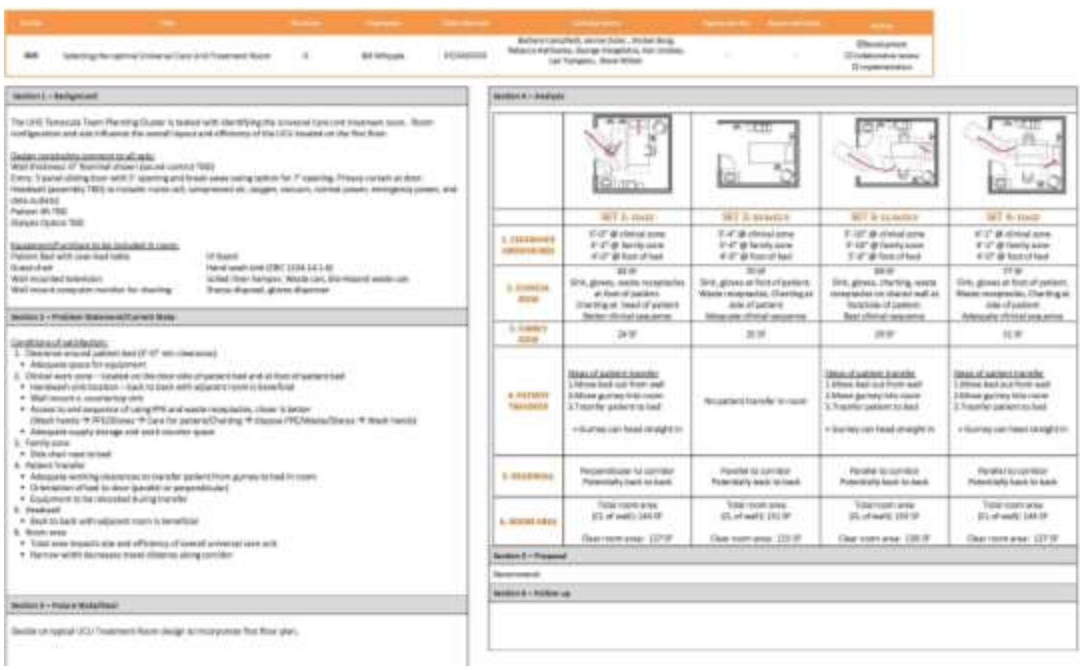
8.2.6 Selecting Location of Hand Wash Sink at Med/Surg Patient Room



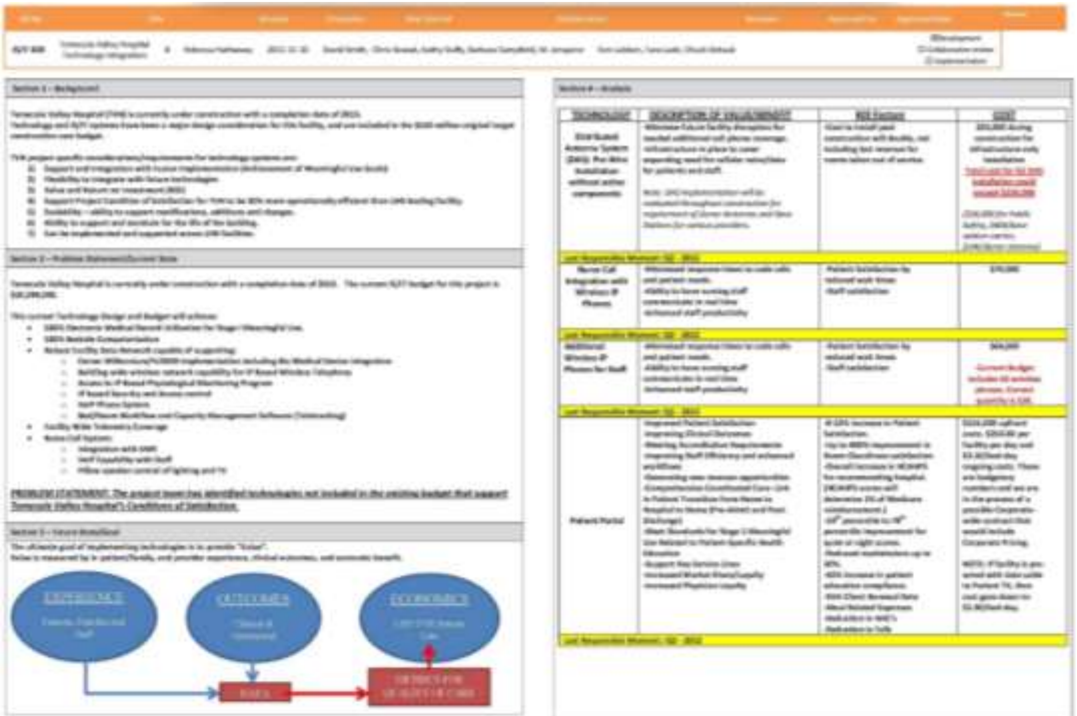
8.2.7 Selecting the Optimal ICU Patient Room Layout



8.2.8 Selecting the Optimal Universal Care Unit Treatment Room



8.2.9 Temecula Valley Hospital Integration



8.3 TVH Lessons Learned Spreadsheet

Temecula Valley Hospital						
	Lessons Learned					
	Issue	**Description**	**Design**	**Contract**	**Field**	ID
Fire / Life / Safety						
	Fire Alarm wiring	Fire alarm wiring does not need to be in conduit. Fire wiring in corridor does not need to be in plenum rated only fire rated.	X			
MEP						
	Underground Conduit Coordination	Coordination of the underground conduits may be valuable for helping out schedule in the field			X	
	Hangers	Check hangers with laser to ensure accuracy			X	
	Trimble	Ensure that dimensions are shown on trimble layout drawings to double check in field			X	
	Seismic	Make sure seismic attachment points are located within ½" to center of flute			X	
	Underground Conduit	Slab on Grade - Slurry on top of electrical in some areas prior to rock to prevent movement			X	
	Trimble	Set tolerance of trimble to 1/8" typical			X	
	Control Points	Control points need to be established and coordinated on every floor prior to generation of trimble drawings			X	
	Trimble	No trimble for underground layout (plumbing)			X	
	Seismic	Siesmic pre-install meeting with IOR's. Seismic drawings are difficult to follow so the seismic engineer helps decipher prior to install			X	
	Underground - MEP	Provide greater installation areas for individual trades			X	
	Underground Electrical	Address electrical heat generation concerns with IOR team prior to installation			X	
	Underground Electrical	Electrical conduits should be installed first, prior to grade beams and plumbing			X	
	Underground Plumbing	Plumbing waste piping should be scheduled after grade beams are complete			X	
	Underground Electrical	Bundle more individual branch conduits together to lower risk of damage & to provide more open area for movement of rock			X	
	Grade Elevation	Check final grade elevation with survey after grade beams are complete and prior to electrical installation			X	
	Depression Layout	Layout all depressions prior to installation of electrical			X	
	Underground Design	Finalize design, OSHPD related changes, and documentation prior to start of work			X	
	IT / IS	IT / IS can be taken for granted make sure enough collaboration and time is dedicated to it.	X		X	
Arch / Struct						

Temecula Valley Hospital

Lessons Learned

	Issue	Description	Design	Contract	Field	ID
	Cross Discipline Review	Look at details in drawings (cross discipline review)	X			
	Local Ordinances	Need to check all local ordinances that may govern. Don't just assume OSHPD takes precedence. Local may be more stringent	X			
	Deferred Approvals	Because we submitted Inc 8 before Inc 1 ISAT has had to recoordinate seismic twice. Deferred approval may have been the way to go, when they are advantageous	X			
	Document Control	Document Control process needs to be put together early and captured in Div 1 specs	X		X	
	Dimension References	Architectural dimensions to walls need to be accurate and consistent, measuring to face of stud, typical	X			
	Waterproofing at prefab showers	Eliminate waterproofing behind prefab showers	X		X	
	Truss Drawings	When doing truss drawings have gauge identified. Typically shop drawings do not incorporate gauges. Future Projects to look at gauges.	X			
	Functional Space Program	Need to find a functional space program and make sure our design supports it	X			
	Endoscopy Room	Make sure Endoscopy room codes and design are reviewed thoroughly	X			
Mock-Ups						
	Mock-up Schedule	Finished mock-up should be completed prior to construction. Timing of construction should be further discussed			X	
Processes - Project Management						
	Field Coordination	Adding select few of the foreman to the pull plan early for key trades will help with coordination			X	
	DCR's Tracking	Use Notevault at onset of job for streamlining of DCR's			X	
	Exterior Wall Track	Due to heating and cinching the steel during erection to get steel straight and plumb, attaching slide clips and or slide track to steel pour stops before erection does not work				
	Lesson Learned Tracking	Put inplace a system to start tracking lessons learned at beginning of job			X	

Temecula Valley Hospital

Lessons Learned

Issue	Description	Design	Contract	Field	ID
Deck Layout	Composite layout for all trades on deck inserts - this is working well			X	
IOR	Bring IORs onboard to look at drawings early			X	
Slurry Backfill	Slurry helped with projects overall schedule in lieu of using native for backfill. The savings to the schedule outweighed the cost of the slurry around the slab on grade.			X	
Pull Plan Turnover	Need to understand what each expectation is on pull plan turnovers. Need to communicate when something is done it is really done	X	X	X	
Pull Plan Sessions	Small batch pull plan sessions works better (2 - 2hr meetings a week vs 1 mtg)			X	
Staff Meetings	Small batch staff meetings 15 minutes a day in lieu one large staff meeting			X	
Onboarding Vendors	It is important to onboard the owner's vendors early and get them involved in the process		X	X	
Go and See Trip	The Wellington Project being ongoing allows for excellent learning opportunities and lessons learned that can be incorporated into this project. Go and see their project with the last planners as their respective work begins at Wellington			X	
Field Communication	Use manlift and foreman trailer to better communicate with craft by posting boards that allow everyone to present suggestions			X	
Fireproofing out of sequence	Fireproofing exterior beam out of normal sequence allowed the exterior wall to go on ahead of schedule			X	
Bigroom Technology	Using Apple TV and television screen is more cost effective than a smart board and allows for a more collaborative environment.			X	
Electronic Pull Plan	Having an electronic pull plan allows for the participants to enter their tags ahead of time and then the team reviews them at the pull-planning session. This also eliminates one person from having to data entry everyone's tags.	X	X	X	X
Shared Layout	All partners should use same control points to ensure consistency and avoid small discrepancies. Potentially on next project one company perform all layout			X	
Specialized Vaccum	Use specialized vacuum in lieu of sweeping			X	
Daily work plan	Utilizing daily work plan sheets to connect field and office better			X	
Internal Productivity Tracking	Sharing internal productivity methods within group for higher level of understanding			X	
Shared Loading Areas	Installed loading areas with a shared yo-yo fall protection system at every floor to make unloading efficient			X	
Visitors	Make sure that all visitors to the Big Room are introduced			X	
Deliveries	Coordinate heavy equipment deliveries with interior framing installation			X	
Field Lunches	Field lunches with tradesman add value and provide a lot of ideas			X	

Temecula Valley Hospital

Lessons Learned

Issue	Description	Design	Contract	Field	ID
BIM Modeling	In BIM model incorporate roof actual section (insulation)			X	
Embeds	Use anchor bolts for HVAC units in lieu of embeds			X	
Pull-Planning	Do not underestimate the shoulder to shoulder and micro pull plans. Shoulder to shoulder should accompany OurPlan.			X	
Permanent Control Points	Set permanent external control points (possibly set in concrete)			X	
BIM	Use common room/collaborative space for entire BIM coordination process including detailing	X			
Survey Points / Control	Overlay survey points with building control points prior to layout			X	
Bench	Always bench in with 3 points			X	
Grade - Beams	Lower grade beams where possible (possibly leave out top portion of grade beams and fill during SOG pour)			X	
Grade - Beams	Have the ability to sleeve top 1/3 of grade beams			X	
Rock backfill	Utilize smaller trucks for loading rock into the building to prevent and damage to work in place (i.e. plumbing & electrical)			X	
Backfill under building	Look into using sand in lieu of rock for fill prior to vapor barrier			X	
Jobsite Office	Removed portions of wall by plan table to open up office area. This helped tie the office together more			X	
Jobsite Office	Added an intermediate size conference room. We had the big room and small break-out rooms but nothing in between			X	
Pull Planning	We have found that by having the partner that is currently driving the scope/schedule leading the pull plan session generates more discussion			X	
Schedule	Label areas in schedule to match areas on the plans to avoid confusion or make nomenclature completely unique			X	
Bent Plate Tolerance	Install a larger C-Channel			X	
Bent Plate Tolerance	1" overhang on top and bottom track			X	
Bent Plate Tolerance	Field weld the bent plate			X	
Metrics	Utilize better metrics related to PPC. We are using PPC vs. completion date. Tasks Anticipated (TA) and Tasks Made Ready (TMR).			X	
First Run Study	When performing 1st run studies it is better to record a cycle rather than a 10 minute span			X	
Hardware schedule	Revit hardware schedule should be cross checked with the actual door and hardware schedule			X	

Temecula Valley Hospital

Lessons Learned

Issue	Description	Design	Contract	Field	ID
BIM Modeling	Make sure that monokote, ductwork flanges, and ductwork insulation is taken into account in BIM model			X	
Communication	Improve communication and make sure what is said is what is understood	X	X	X	
ACO	Don't have ACO onsite on the day it rains (Densglass)			X	
Pull Planning	Continue to instill importance of bringing up issues on daily check-ins. Don't become complacent	X	X	X	
Operations Issue Log	Generate an operations issues log for owner items/changes and direction to proceed from UHS to GC PM to the Team			X	
5 Why's	Perform 5 Why's sooner so that the changes can be implemented immediately	X	X	X	
Design/Construction Pull Plan	Breakdown the gap between design and construction on check-in / pull plan	X		X	
Clusters	Maintain continuity in clusters from design through construction. Have a handoff as people change during the project.	X	X	X	
Safety Tracking	Track Safety like production to make it more visible			X	
Fireproofing	FP was sprayed too thick in some places coupled with some construction tolerances created perceived elevation bust			X	
Fireproofing	Issue and explain FP shop drawings to all effected trades. FP could have been scraped in lieu of re-piping			X	
Schedule	As a reminder schedule and sequence should continue to be challenged and discussed throughout course of he project			X	
Schedule	If a mock-up is not feasible look closely at renderings and elevations as a group to reach consensus			X	
Medical gas fittings	Medical gas drop fittings can be reduced by rising vertically or no more than a 45 degree angle			X	
Floor Mounted Sinks	At floor mounted sinks install 1" rock and then 1" concrete for blockouts so that area is safe and sink is protected until needed			X	
Tools	Give workers ownership of tools by putting them in charge of their own and giving them their own storage carts			X	

8.4 TVH Implemented Innovations Spreadsheet

Temecula Valley Hospital

Implemented Innovations

	Innovation	Description
1	Application for I Pad for requesting equipment	
2	Sissor lift plan table / board	
3	Kiosk's	
4	I pads for foremen	
5	Use of cordless tools more than any other job	
6	QR code program	
7	Having a trash cart below when knocking out floor cans to reduce mess below	
8	Vacuums vs. brooms and clean sweep	
9	Modify existing tools to make more efficent (plumbers grinding down nutdriver to make tightening of bands easier)	
10	Use of Notevault to combine DCR's from both trade partners and some commoditity contractors	
11	Use of backing tool to reduce the time of laying out wall backing	
12	Plasma cutter vs. 4" grinder for cutting holes in bottom track	
13	portable chop saw tables	
14	lay-out table for stud layout on bottom track prior to laying on the floor	
15	Visuals for backing locations to ensure correct locations	
16	Project Inertia highlighting inspection area electronically	
17	Framing mock-up of all connections to aid inspections	
18	Utilizing a 3-legged ladder to allow for access to corners and through framing	
19	Ground, Neutral, and hot wires are being combined by manufacturer in barrel in lieu of performing in field on separate spools	
20	Box layout with story pole	
21	Screed Z-clips while fire-proofing is wet so tht it does not need to be scraped later	
22	Purchased right angle cordless drills in lieu of straight drills so that exterior studs can be screwed next to I-Beams	
23	Sectioning hanger batches by area and not be system and area	
24	Utilize onsite med gas pre-fab trailer in lieu of shop fab to lower inspection costs	
25	Fabricate sheet metal pans for the scissor lifts to hold tools and materials	
26	Electrical Prefab carts	
27	Purchased cordless drywall screw guns based on worker feedback	
28	Added spool sheets to kiosks and allow worker access at home	
29	Pre-program CAV controllers with battery and inverter in lieu of requiring permanent power	
30	Utilize Tite-end true torque nut in lieu of standard anchor bolt. Bolt snaps off at required torque and torque test not required	
31	Plug tail device in lieu of standard plugs. Plugs only have to be connected on the backside reducing labor and troubleshooting	
32	To protect prefab showers a sprayed on latex is going to be utilized.	
33	Have lunch with workers to increase transperancy with workers and spur incremental inovation	
34	Plangrid - Utilizing plangrid program to track rework and potentially use for punchlist / signoffs	
35	Continuous Bazooka for tapping operations.	
36	Utilizing quartely field surveys to help improve communication and extract ideas	
37	Lead man coordination meetings in lieu of just GF's to improve communication	
38	Utilizing Apple Facetime to quickly communicate a visual to engineers	
39	"Carnie Hooks" are being utilized for cord management. Inexpensive option can be handed out to workers. $3.00/ea.	
40	Utilize low torque screw guns for backing due to heavy gauges.	
41	Sheet metal made a shroud for the chop saws in lieu of the dens board to catch sparks/debris.	
42	Extension for roto hammer/torque wrench to install soffit top track anchor bolts. Made in the field by JM.	
43	Taking pictures with notes in them so that when the picture is issued to the field it is known what needs to be done.	
44	Utilize inverter to test CSFD's with field staff and IOR's prior to permanent power.	
45	Utilize countdown clocks for different milestones throughout the building.	
46	Utilize 26 ga. sheet metal in big room so that items can be magnetized to the wall.	
47	Use Sprayer for final pass on Level 4 Finish will improve productivity.	
48	Use a group washout for taping operations	
49	Utilize a dashboard to reach information on the project more efficiently	
50	Utilize 360 interactive project tour linked to floorplans	
51	Utilized dust muzzle bought from local store to mitigate dust from concrete cutting. This item costs approximately $60.00. Similar products sold by Hilti are	
52	Ultra Ever Dry Special coating so that liquids and other materials do not stick to desired surface.	

8.5 TVH Ah Ha Moments Spreadsheet

Temecula Valley Ah Ha Moments Directory	
Name	Title
Seena Hassouna	Architect
Rebecca Hathaway	Mechanical Trade Partner

Kristen Hill	Lean Coach
Bob Kenz	Fire Protection Trade Partner
Margie De Laurell	Engineer
Marius Nimitz	Architect
Ken Lindsey	Mechanical Trade Partner
Dave Seastrom	General Contractor
Nancy Squartino	Owner
Ward Thompson	Architect
Lee Tsangos	General Contractor
Steve Wilson	Architect
Steve Yots	Mechanical Trade Partner
George Zettle	General Contractor

Ah Ha Moments		
Date	**Who**	**Moment**
12/7/2010	Seena Hassouna	The use of A3's. The team was working on the ICU redesign issue. He'd been asked to type up a summary of a phone meeting the team had with OSHPD and discussed it on the core team call. As he begun the summary he realized that the A3 was a tool he could use to present the summary but also begin tracking some solutions he was working with. He copied and pasted his summary into an A3 template Jessica H. sent him and then he added some graphics that he was working on as well. The A3 was well received and it really helped everyone to get an understanding of the issues the team was having.
12/15/2010	Steven Wilson	Was pleased to know that the process of breaking the submittals down into increments and submitting them would help with the speed of OSHPD's review. OSHPD's review comments on the construction documents helped with flagging issues that would perhaps occur with later design.
12/15/2010	George Zettle	Was touched by the threadig of emails showing compassion and concern about our team members (Tom M.)
12/15/2010	Rebecca Hathatway	Wasn't to clear about the design sets by just looking at them, but after talking and listening to the team communicate she then understood. By understanding what was going on she then was able to address the A3. She also learned that no matter what OSHPD threw at us, we were able to fix it.
12/15/2010	Steve Yots	Shared with us a comment that OSHPD said "This was the best project in years".
12/15/2010	Kristen Hill	Pointed out an ah ha moment the Site Planning Team had. It was a lesson learned on how to communicate with one another. Basically the requests (post-its) needed to be straight to the point and discussed. This way it could be a shared decision on whether that request is really needed.
1/5/2011	Dave Seastrom	Review of the owners manual that Jessica and Rebecca are working on, gave him a better understanding as to why our team is creating one.
1/5/2011	Ward Thompson	While reflecting on this project during his holiday break, he realized that he is really having a good time working with everyone. He feels that people in the "Big Room" are *friends*.
1/5/2011	Kristen Hill	Wanted to "Pause and Reflect" on Ward's Ah-Ha moment. She says it goes back to the PDCP (plan, do, check, principals). This increases the trust within our group. She suggests that we adjust to make PDCA a part of the process in the "Big Room".

1/5/2011	Seena Hassouna	Reflected on the project during his holiday break and felt that it hadn't consumed him as with other projects did in the past. There were no worries.
1/5/2011	Ken Lindsey	Shared his appreciation of Lee, Tom M., and Doug work during our holiday break.
1/5/2011	George Zettle	The Budget Cluster meeting had very good communication with the progress of all of collaboration of good work ethics.
1/12/2011	Nancy Squartino	Currently working on another project that is not using Lean Principals. During a discussion she found that it was hard to communicate solutions to problems without an A3. She admits that once you are exposed to Lean Principals you wish all of your projects works that way.
1/12/2011	Rebecca Hathatway	Last Friday, the A3 Funding team was working on completion. During this process everyone focused on making it a piece of art and as the tool it really is. They needed to re-create the A3 in order to tell its true story.
1/19/2011	Margie De Laurell	There were environmental occurences that could set back the schedule. She talked it over with Steve W. and asked for his help with some tracking. She then realized that she could of taken the initiative and done it herself.
1/19/2011	Steve Wilson	During the KoP presenatation he was impressed with how Rebecca, George V., and Jessica understood their clients needs. They addressed issues that were sensitive to this project in a way that made the client realize (1) it was there, (2) there is a solution, (3) we will work on it together.
1/19/2011	Kristen Hill	Reliable Promise! (1) Component to perform a task (is there enough time on the calendar) (2) Usually is done out of sincereity, with in mind I'll do it on the contrary (I'll do it when I know I really can't) (3) If I can't keep the promise, must go back to the team and re-evaluate it
1/26/2011	George Zettle/ Kristen Hill	While working on the '*A3 Advance with Lean Skills*' George discovered that no matter how you start an A3 your thought outcome doesn't happen. The solution that comes from an A3 is unforeseen and is the reason why A3's are so successful.
1/26/2011	Steve Yots	At his home office, his colleages tell him that he's changed. His thought process and procedures truly reflect the Big Room culture.

2/1/2011	Lee Tsangos	He thought agendas and pull planning could be done more efficiently be a few people. Then he realized that it takes the whole team to participate in order for all to be satisfied with the outcome. It's really hard to try and plan for everyone else if they do not participate. It takes the team to have a successful Pull Plan session as well as a successful agenda.
2/1/2011	Bob Kenz	He was able to create a Pull Plan for a dinner he planned with his wife. Their dinner was a success and very organized.
2/8/2011	Seena Hassouna	With a deadline approaching the idea of experimenting a new process to reach a goal is definitely a Lean process. The traditional way would be to reach that same goal as we would normally do it. It's all about taking on new ways as a team to reach the team's goals.
2/8/2011	Kristen Hill	Within breakdowns like a OSHPD Increment Submittal, there was discussion about whether to try something new or stick with the traditional way. The traditional way is the "know what to do" based on individuals experiences....where the Lean process is the "experimenalt/learned on the fly" which is more of a team effort. Discovering new ways and exploring them as a team is the Lean way.
2/8/2011	Marius Nimitz	Client supports experimentation with work process.
2/8/2011	George Zettle	Even though it is hard to redesign how we do our work, it is a must to achieve the overall success.

8.6 Sutter's 5 Big Ideas Survey

Temecula Valley - Cultural Outcomes Survey

The goal of this survey is collect information about the "softer" cultural outcomes from Temecula Valley which cannot be fully captured in the project's financial outcomes and KPIs. For each of the 5 questions, state the degree to which you agree or disagree with the following statement.

The team collaborated, "really" collaborate

- 1. Strongly disagree
- 2. Disagree
- 3. Neither agree nor disagree
- 4. Agree
- 5. Strongly agree

The project was optimized for the whole rather than optimized for local maximas.

- 1. Strongly disagree
- 2. Disagree
- 3. Neither agree or disagree
- 4. Agree
- 5. Strongly agree

The team tightly coupled learning with action

- 1. Strongly disagree
- 2. Disagree
- 3. Neither disagree or agree