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UCSF Real Estate

Lean Project Delivery Guide

A guide for major capital projects

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1. Purpose of this guide

The *UCSF Real Estate **Lean Project Delivery Guide*** is part of an initiative to develop Project Management Standards for the University of California, San Francisco (UCSF) that incorporates existing industry, national, and international best practices on lean design and construction. The purpose of this document is to provide guidance and shared understanding on the intent of lean practices selected by the University to support its delivery method of major capital projects.

UCSF Real Estate believes that outstanding outcomes can be achieved through a collaborative project delivery model that incorporates lean design and construction methods. Such model includes the selection and alignment of team members to support collaboration, a focus on value generation, and the elimination of waste and rework (Figure 1).

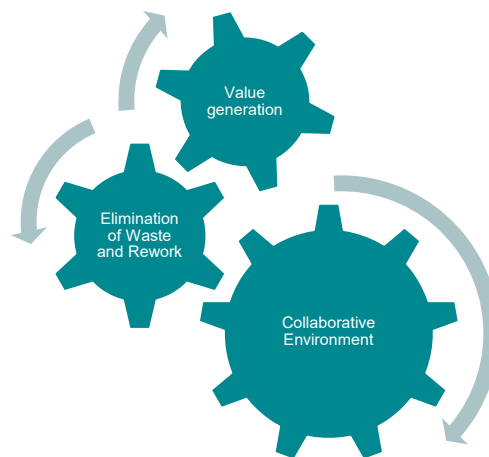


FIGURE 1: ACHIEVING SUCCESS THROUGH LEAN PROJECT DELIVERY

This guide describes specific approaches that have been successfully adopted at UCSF Real Estate projects that have contributed to achieving those objectives. It also includes examples of techniques and tools that support the implementation of specific methodologies, such as Target Value Design (- Delivery) and the Last Planner™ System. Different levels of maturity for each of those practices are also provided to support their successful implementation during project delivery.

The practices and terminology presented in this guide are aligned with those used by the Lean Construction Institute (LCI) and the International Group of Lean Construction (IGLC)¹. The examples are from UCSF Real Estate projects and were kindly provided by companies that are currently working or have worked directly with UCSF. This guide provides a starting point for lean implementation in major capital projects (investments ~ 100 to 500 million) and will be revised and updated to reflect the advances in the application of lean design and construction at UCSF Real Estate projects. Therefore, UCSF welcomes your input and contribution with examples and practices that demonstrate the successful adoption of lean design and construction methods. To contribute with your feedback, please contact UCSF Capital Planning Sr. Lean Manager at patricia.andreitillmann@ucsf.edu.

¹ For more reference, including papers, presentations and other resources please access LCI database at: <https://www.leanconstruction.org/> and IGLC database at: <http://iglc.net/Papers>.

2. Collaborative Project Delivery

2.1 Background

In general, when it comes to project delivery, public owners enjoy less freedom of choice than their private sector counterparts. Following California Public Contract Code provisions, the university can use different forms of delivery: construction manager at risk, cost-plus, design-build, multiple-prime, and job order contracting. Multi-party agreements such as those found in the private sector, however, are not permitted. California law does allow for prequalification of contractors, which UCSF advocates and uses whenever possible for its major projects. Since 2006 UCSF is part of a Best Value Construction Pilot Program. This program allows the University to use multi-criteria contractor selection (not just lowest price) to establish incentives and increase alignment among different parties, while incorporating public policy objectives in the procurement of construction.

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

Within this context, UCSF Real Estate believes that the desired project outcomes can best be achieved through Collaborative Project Delivery that incorporate Lean Design and Construction Methods. The university has experienced significant benefits from using Lean design and construction compared to its experience with traditional capital project delivery methods. Improvements include consistent on-time delivery; avoidance of claims and costly adjudication; competitive, predictable costs; improved design and building performance, crisp and effective start-up and commissioning; and improved end-user satisfaction².

The chosen Collaborative Project Delivery method is inspired by Integrated Project Delivery (IPD)³: based on trust, collaborative decision-making, early involvement of downstream players on design, intensified planning, open communication, and behaviors that support learning, candid conversations and optimization of the project as a whole. The use of such model has brought positive outcomes for the university, with projects that are

In Collaborative Project Delivery, Lean Design and Construction Methods are utilized to support outstanding team performance and deliver improved project outcomes, i.e. increased safety, decreased claims, and optimum design and construction solutions that are in alignment with the project's value proposition.

² For full description on how UCSF is benefiting from lean practices see Bade and Haas (2015) available at: leanconstruction.org/media/docs/415GFRLeanConstruction.pdf

³ For a comprehensive research done on the benefits of IPD projects and guidelines for implementation see: UMN, IPDA and LCI (2016) and IPDA, CIDCI and Charles Pankow Foundation (2018), both available at <https://www.ipda.ca/>.

Principles of Collaborative Project Delivery

- *Optimum solutions are developed through cross-disciplinary work, involving the expertise of multiple professionals;*
 - *Intensified design and planning leads to savings during project execution;*
 - *Desired outcomes are best achieved through collaboration, open and direct communication;*
 - *A system should be improved by focusing on the whole and not on individual pieces; and*
 - *Ability to overcome problems and achieve outstanding performance depends on how well teams are able to bring problems to the surface, have candid conversations, and proactively change course of action.*
-

The establishment of more collaborative environments is allowing the AEC industry to overcome the deficits of traditional approaches to deliver projects. The integration of project teams allows for a more holistic perspective to value generation, greater efficiency and greater ability to foresee and overcome problems.

2.2 Collaborative Project Delivery Mechanisms

Five mechanisms are identified as effective to support collaboration on projects. Those are (Figure 2):



FIGURE 2: MECHANISMS TO SUPPORT COLLABORATIVE PROJECT DELIVERY

2.2.1 Team selection based on mindset and alignment

Observing the restrictions of public contracting code, the selection of project team members, inclusive of consultants, subcontractors and other participants at UCSF Real Estate projects takes into account alignment with the project's team culture and goals. Although most of the times the selection of subcontractors and other consultants fall into the Architectural Firm's or the General Contractor's responsibilities, different approaches have been used to collectively select new team members⁴:

⁴ For more information on how supplier evaluation can impact product quality in construction, see for instance Alves et al. (2017) available at www.iglc.net

- Selection based on similar criteria used by UCSF's best value selection process (including experience with specific Lean tools and BIM, for instance) - see Figure 3 for example of language used by contractor on Request For Qualifications (RFQ);
- Selection of partners using techniques to define evaluation criteria together and priorities while choosing among different companies; and
- Interview processes, including visits to workplaces, headquarters, local offices and/or fabrication facilities.

BIDDER QUALIFICATIONS:
To allow University/DPR to evaluate Bidders, each Bidder must submit a completed Statement of Experience Form before Bidder Qualification deadline. If the Statement of Experience Form is not submitted with all required qualifying information, Bidder will be deemed not qualified to continue with Step 2 process and submit a Proposal.


A. BP #1: HVAC and BAS:
To be eligible for consideration for award, bidder must complete the **HVAC and BAS** Statement of Experience Form, which requires that the bidder:

1. Has completed three (3) projects of similar scope and values in the past 10 years, as described under the General Description of Work.
2. Has completed three (3) projects in the past 8 years with a contract value of your scope of work **\$20,000,000** or greater at time of completion.
3. Has completed three (3) projects as design build contractor of record in the past 7 years.
4. Of the projects in Item #3 above, one (1) was a laboratory.
5. Has completed (3) projects utilizing Lean Construction Methods.
6. Has completed (3) projects utilizing Target Value Design.
7. Has completed (5) projects designed using BIM and Total Station or other enhanced construction technology.

FIGURE 3: EXAMPLE OF LANGUAGE USED FOR SUBCONTRACTOR RFQ.

In addition to selecting new team members based on their alignment to team culture and goals, project teams have also used an on-boarding strategy to communicate the team's culture to new members (see Figure 4 for example of on-board meeting agenda). The onboarding material reflects team's philosophy, helping to establish and maintain a culture that supports collaboration, open communication and the adoption of lean principles.

Onboarding for New Partners | UCSF Block 23A
Joan and Sanford I. Weill Neurosciences Building



AGENDA

8:30 – 10:00 AM:
Project Overview

1:00 – 2:30 PM:
Team Philosophy & Lean Culture

FIGURE 4: EXAMPLE OF ON-BOARDING MATERIAL – COVER PAGE AND MEETING AGENDA.

2.2.2 Co-location to support cross-disciplinary work

At UCSF projects, it is required that project teams, inclusive of all consultants, subcontractors and other participants working on the project, be co-located for the duration of their work at the University proposed Big Room location on or near the project site.

Co-location is a mechanism to increase direct communication, cross-disciplinary work and expedited problem solving. Project team members are encouraged to communicate directly as necessary, organizing the Big Room in a manner that allows for the establishment of both a productive and collaborative environment, while engaging key decision makers on a proactive manner. Figure 5 presents an example of Big Room layout.

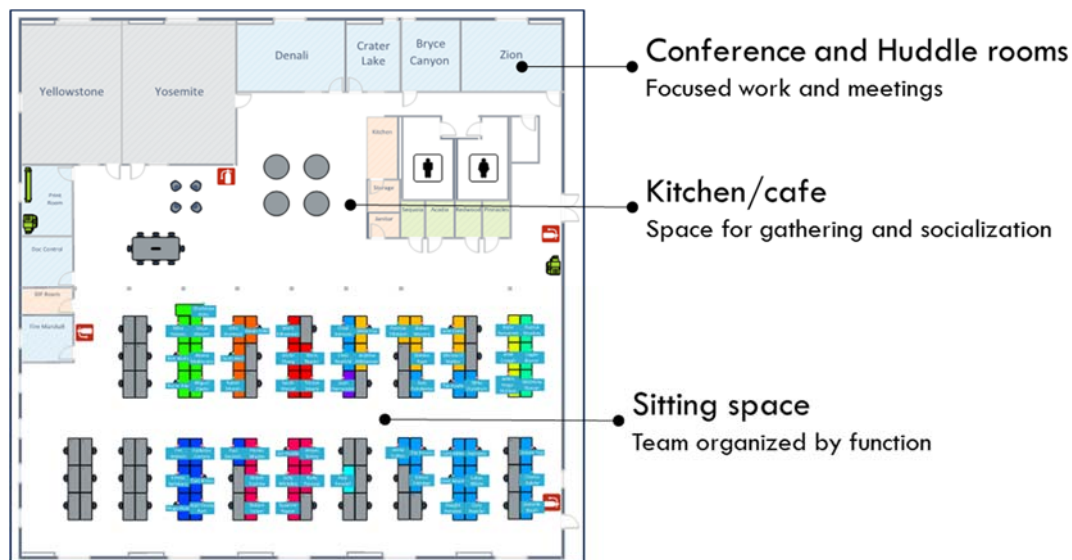


FIGURE 5: EXAMPLE OF CO-LOCATED OFFICE SPACE FOR THE PROJECT TEAM (THE BIG-ROOM)

Teams are encouraged to establish a productive work environment, which includes defining the right cadence, frequency of meetings, meeting agendas and any supporting software to allow for increased productivity. Some teams have relied heavily on technology to support increased communication, i.e. use of smart boards and 3D modelling visualizations to allow for interactive design sessions in which team members can better visualize, communicate and solve problems together. Conversely, other teams have improved their efficiency by implementing simple improvements, such as agreeing on meeting purpose, agenda and expected outcomes as a means to improve productivity.

Having the right people in the room is key to fulfill the purpose of a big-room. Identifying and engaging key decision makers in big-room activities allows for a greater ability to foresee potential problems and develop solutions that are right at the first time, avoiding unnecessary rework. Also, effective cross-disciplinary work is only possible when team members can freely share concepts and ideas to improve overall Project outcomes. Within the limits of licensing or professional registration and reserving each party's responsibility for its portion of the work, project participants are expected to collaborate and generate improvement ideas to other team members, while also considering suggestions regarding their portion of the work or services.

2.2.3 Governance Structure in a collaborative environment

At UCSF projects, decisions of the project management team are made in a collaborative environment. For that, a governance structure that allows a more streamlined decision-making process is set in place. Such structure includes consultation with key stakeholders when necessary and an escalation route to support the informal resolution of unsolved issues.

Project decisions are made on a weekly basis involving key members of the Project Management Team. When a decision cannot be reached, or may implicate a significant impact to project costs and schedule, the Senior Management Team can be consulted. In regards to dispute resolution, an informal resolution of issues is prioritized. Assigning a project neutral allows teams to escalate issues even to a higher level, increasing their ability to settle unsolved issues when necessary.

The decision making structure should be set with the primary intent to support the work of the project team (Figure 6) – allowing for those who are doing the work to have a greater autonomy, while proactively engaging key stakeholders and upper management to provide guidance and support on removing road blocks for effective teamwork.

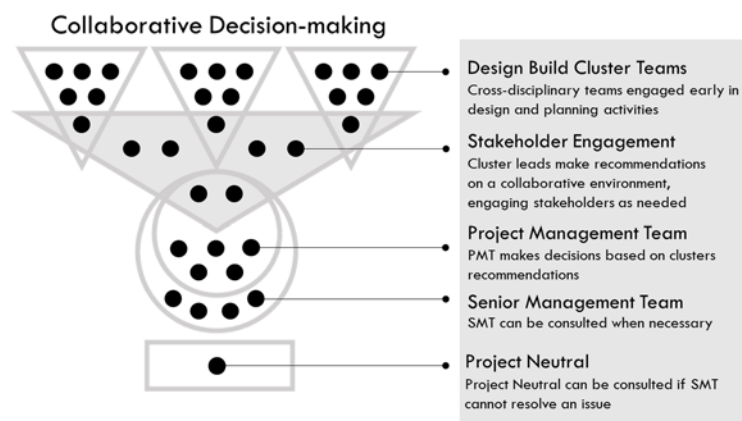


FIGURE 6: GOVERNANCE STRUCTURE TO SUPPORT COLLABORATIVE DECISION-MAKING

Some teams have opted to establish a Project Solutions Group (PSG). The intent of this group is to allow for quick decision-making, avoiding any impact to field activities. In the Medical Center project, for instance, key decision makers from the owner side, GC, architect and major trades would meet every day in the Big Room from 9:00 to 10:00 to provide direction and clarification to any question related to the execution of work.

2.2.4 Aligning goals and removing barriers for collaboration

In an integrated team, the focus of improvement efforts is on the Project as a whole. Efforts to optimize any individual portion of the work or service should benefit the entire Project. In order to support teams to work towards common goals, the University selected some mechanisms to help removing barriers for collaboration and achieving greater alignment. As a public institution, UCSF has limited options compared to an owner in the private sector. Three main mechanisms to support alignment of goals and increase collaboration at UCSF projects are as follows:

- Initial University funded incentive pool;

- Opportunity to earn additional incentive compensation through shared savings (based on cost of work reduction); and
- Pooled contingency program.

It is paramount at UCSF projects that different stakeholder groups participating in the project efforts (permitting, design, operations, maintenance, etc.) are considered as project team members. Project teams are encouraged to include those stakeholders on any alignment activity, as they see fit.

2.2.5 Monitoring and improving Team's performance

Regardless of the type of delivery method, the creation of shared goals allows project teams to increase alignment and focus on continuous improvement⁵. As part of creating shared goals, different strategies can be used to support continuous improvement throughout the delivery process. Those include: (a) training focused on creating a shared understanding of lean culture and principles, and (b) exercises for setting agreed goals related to team's performance and desired project outcomes.

Both strategies allow teams to develop Key Performance Indicators (KPIs) which are not only related to project performance but can also be used to measure the health of the team. Such effort supports continuous improvement and contributes to achieve better alignment among team members as it gives project team members an opportunity to have candid conversations about any emerging issue. As progress results are discussed, countermeasures can be developed and implemented.

⁵ For previous research and examples on setting common goals in construction projects please see: Tillmann et al. (2014), available at <http://iglc.net/Papers>

2.3 Collaborative Project Delivery Maturity Matrix

The table below presents different levels of maturity while establishing a Collaborative Environment. Observed practices and their expected effects are listed. This maturity matrix is intended to provide a quick guidance for teams that are seeking to establish effective Collaborative Project Delivery (Figure 7).

| <i>Collaborative Project Delivery</i> | |
|---------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | <div>Practices</div> <div>Effects</div> |
| Level 4 | <div> <ul style="list-style-type: none"> + There are efforts to sustain a lean and collaborative culture (trainings, presentations, improvement programs) + Surveys or other tools are used to support reflection and continuous improvement + Technology is effectively used to support decision making and expedited exchange of information </div> <div> <ul style="list-style-type: none"> + Team members support each other in their lean/IPD journey + Achievement of progress against performance goals is tracked and celebrated + Teams accept challenges to improve performance and engage others in the effort + Teams can make decisions quicker and effectively avoid rework with technology adoption </div> |
| Level 3 | <div> <ul style="list-style-type: none"> + Big-room layout and team structure allows for cross-disciplinary work and effective decision making + KPIs are publicly displayed and discussed on a regular basis to support improvement + Shared goals are established and tracked + Big room activities have a high level of participation from project team members + On-boarding strategy for new team members + Kaizen events and improvement efforts are undertaken to improve productivity and big room functionality </div> <div> <ul style="list-style-type: none"> + Project solutions are developed from a multi-disciplinary perspective + Problems are quickly revealed and worked on + Interpersonal relationships are developed + Project team members are engaged in Big-room activities and feel they are part of the team + Project team members have a shared understanding of and can easily explain current project status and goals to achieve + Improvement efforts are highly attended by project team members </div> |
| Level 2 | <div> <ul style="list-style-type: none"> + Well defined governance structure, meeting cadence and agendas appropriate for each level + File sharing is effective and all team members can easily access relevant information + The project team sits by function on big room and establishes some ground rules for working together </div> <div> <ul style="list-style-type: none"> + Co-location support cross-disciplinary work and silo dissolution + Co-location is effective for quickly revealing and solving problems + Project team members can easily access relevant information </div> |
| Level 1 | <div> <ul style="list-style-type: none"> + The project team has candid conversations about project costs, risks and contingency allocation + Contract is discussed, negotiated and all clauses agreed upon + Most team members (the ones that bring more risk to the project) are selected early and based on mindset and alignment </div> <div> <ul style="list-style-type: none"> + The team makes collective decisions about risks and contingency allocation + Team is aligned and responsibilities are well understood + Selection process is agreed by key team members and current performance of participating members/companies is assessed in a collaborative effort </div> |

FIGURE 7: COLLABORATIVE PROJECT DELIVERY MATURITY MATRIX

3. Value Management

3.1 Background

Value generation refers to the process of: understanding customers' needs, designing a product and a production system that satisfy those needs, and measuring perceived value throughout project delivery. Value generation is one of the fundamental ideas of the lean philosophy, which advocates that value should be determined from the point of view of the customers.

Having a strategy for managing value generation in construction projects is paramount, especially in complex projects where the customer is represented by myriad stakeholders. Often, different stakeholder groups have conflicting requirements and expectations that are not aligned with the project's value proposition and design goals. Thus, generating value does not only include delivering a project that will fulfill its purpose and attend to the needs of these multiple groups, but also includes managing and reconciling multiple and different stakeholder expectations and requirements within project constraints.

The rationale for including a value generation session in this guide is to benefit from major lessons learned from prior projects. Those include:

- Managing stakeholders expectations is paramount on complex institutional projects;
- A misalignment on expectations can bring negative impacts to project schedule and budget;
- More streamlined decision making process generally results from the involvement of key stakeholders in the design process in a proactive manner; and
- Decision-making and investments assessments are facilitated when it is possible to visualize the progress of design performance goals in a holistic manner.

UCSF's main expectations regarding value generation is to avoid rework during design development and making sure all stakeholder groups are heard and satisfied with the project outcomes.

Value Management Principles

- *The success of a building is measured by how well it fulfills its purpose and accommodates the needs of multiple stakeholder groups;*
 - *Stakeholders may perceive value differently and have different expectations and requirements that need to be managed;*
 - *Generating value involves designing a solution based on a collective understanding of purpose, needs and constraints;*
 - *Generating value also involves refining the solution and aligning expectations as new understanding (on purpose, needs and constraints) is gained; and*
 - *Perception of value involves an assessment of trade-offs between what is given and what is received in return, those trade-offs are in the core of design decision-making process.*
-

3.2 Value Management Mechanisms

Four mechanisms are identified as effective to support collaboration on projects⁶. Those are (Figure 8):

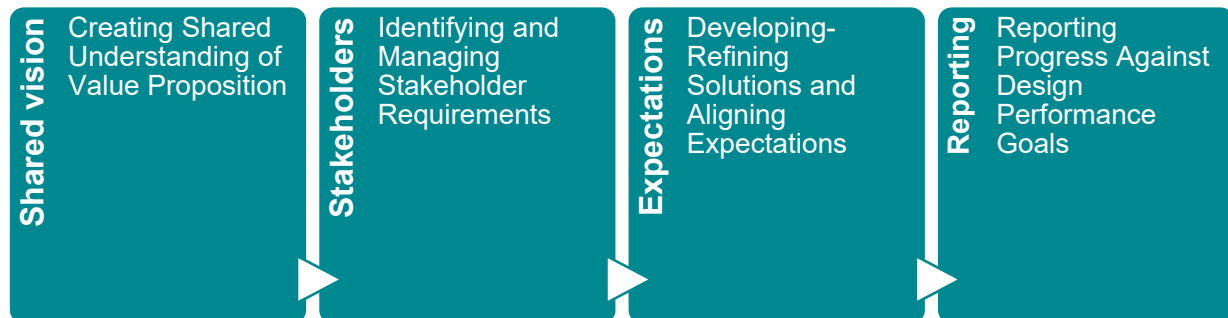


FIGURE 8: MECHANISMS TO SUPPORT VALUE GENERATION

3.2.1 Shared Understanding of Value Proposition

Every project is initiated for a reason and has a purpose to fulfill. Clarifying the need and setting goals to accomplish is part of an investment justification process and generally memorialized in the Project's Business Case. At UCSF, different documents depict the vision for the project, from clarifying the needs and justifying the investment, to setting design guiding principles and performance criteria. Those documents include: the *Project's Business Case*, the *Project's Charter* and the *Design and Performance Criteria*. The information in these documents describes the project's value proposition. Teams have used this information to create a shared understanding of the project's value proposition guiding principles that support design. The example on Figure 9 was created to be part of the projects on boarding material and presented as new project participants come on board.



FIGURE 9: DESIGN GUIDING PRINCIPLES DIAGRAM CREATED FOR ON BOARDING PURPOSES

⁶ For example of value management approach, see Emmitt et al. (2005) available at <http://iglc.net/Papers>

Other strategies have been used by project teams to create a shared understanding of the building's value proposition. A great example are users' presentations throughout different project design. These types of presentations were an initiative of the UCSF Medical Center during the construction of the Hospital and have been very impactful on helping teams understand the overall purpose of the building and create shared awareness of "why we are here". In these presentations, UCSF users provide an inspirational speech, which includes explaining aspects of their work, how they are going to use the building and why the building is important to what they do.

"...This is about people working together as teams and to have the patients come to a place where they see all this going on in this whole neurosciences campus."

Sanford I. Weill, Philanthropist – Extract from Inspirational Presentation to the Project team

3.2.2 Identifying and Managing Stakeholder Requirements

An important component of value management is the ability to understand and manage multiple stakeholder requirements, transforming them into product and process specifications. UCSF Projects generally involve multiple stakeholder groups, whose requirements and expectations might be conflicting. One important step is identifying upfront who are the key stakeholders that need to be involved in the design process or might be affected by and influence the project's outcomes. Figure 10 presents a list of stakeholders whose expectations need to be managed. While some stakeholders might be directly involved in the design process, others might influence project outcomes and have expectations that need to be aligned with the value proposition.

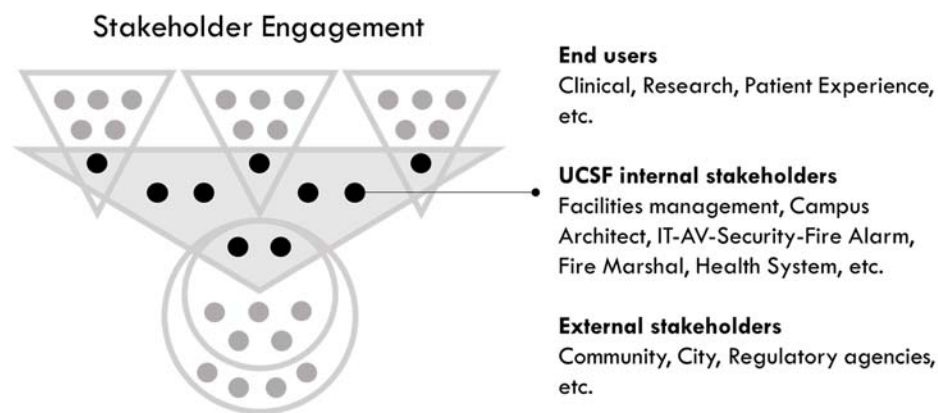


FIGURE 10: EXAMPLE OF STAKEHOLDER GROUPS INVOLVED IN UCSF PROJECTS

In order to adequately manage stakeholder requirements, projects teams undertake a mapping exercise, identifying key stakeholders that will be active participants in the design process and organizing their participation throughout design development. The example below (Figure 11) depicts a schedule of user and stakeholder meetings necessary to achieve a design milestone on time. On this effort, the project team also assigned meeting leaders, to allow matching capacity to load and balance the number of meetings per leader.

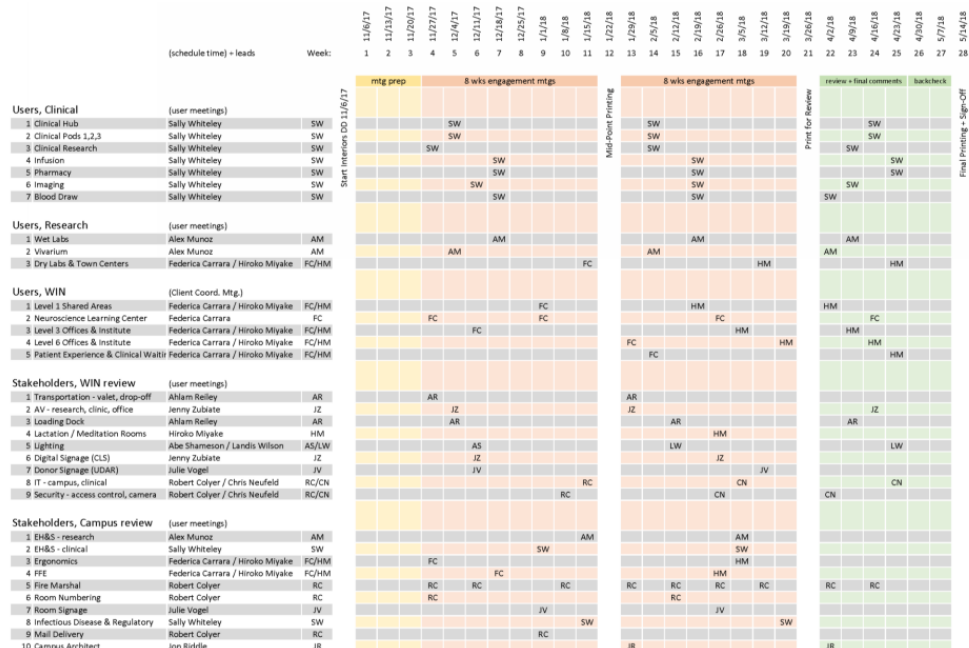


FIGURE 11: EXAMPLE OF MEETING ORGANIZATION TO ACHIEVE A DESIGN MILESTONE

As important as identifying key stakeholders is understanding the right moment to make design decisions. This can be supported by techniques such as pull planning (See session 5) or other production planning and scheduling strategies. The key is to help team members, key stakeholders and decision makers to be aligned and understand the Last Responsible Moment (LRM) to make design decisions. While considering design alternatives, the LRM for one alternative is the time at which, if that alternative is not selected and pursued, it is no longer [economically] viable (P2SL, 2017).

3.2.3 Developing-Refining Solutions and Aligning Expectations

To make sure stakeholders are engaged and their expectations are aligned with the development of the design, teams have been using pre-design sign-offs at the end of each design stage. These meetings occur prior to the completion of a design milestone, when drawings (interiors package) are 90% complete. The workshops involve key stakeholders and are intended for reviewing and making adjustments to drawings before they are 100% complete. This allows stakeholders to provide input and the team to make adjustments in a more proactive manner, before issuing a set of drawings for formal review.

Another approach that project teams have used to make sure expectations are aligned is to organize monthly report-out meetings with multiple stakeholders. These meetings involve different groups of stakeholders that come to the Big Room for a half-day presentation. The report-out includes the revision of design goals, achievement of design intent and updates on overall project progress, including budget and schedule (Figure 12).



FIGURE 12: ALL HANDS MEETING – DESIGN OVERVIEW AND PROJECT PROGRESS.

Another aspect of formation and alignment of expectations is individuals' ability to visualize and predict how the building will perform. Increasingly, virtual reality and simulation is also playing an important role in the refinement of project solutions and alignment of expectations. Different forms of simulation are used by project teams to support a better understanding of buildings—from its operation, use, and energy consumption to construction methods and techniques.

BIM provides the platform for simultaneous conversations related to the design of the "product" and its delivery process, and is a useful tool to help stakeholders visualizing the multiple variables that contributes to building and aligning expectations. Even when technology is not utilized, UCSF project teams rely on mock-ups, visits to similar projects and material samples to make sure all different stakeholders are aligned regarding their expectations and what it will be delivered.

3.2.4 Reporting Progress against Design Performance Goals

The *Design and Performance Criteria* provides a starting point to agree on performance goals and check design progress against those goals. As design progresses, variations to the baseline set on that document should be tracked and provided at each stage of design completion. Major elements to track expected performance variation include (some are expressed in the KPI session at the end of this guide):

- Programmatic performance (at min. assignable sqft and gross sqft)
- Seismic performance
- Sustainability and Energy performance
- Systems durability performance
- Maintainability and operability performance
- Life cycle costs performance
- Constructability performance

At the end of these different design stages, a reconciliation process also happens if the team observes a discrepancy between expected and actual performance. The reconciliation involves teams evaluating any discrepancy between the drawings and project requirements, as well as submitting a plan to reflect how the project objective can be achieved within the expected budget and agreed time frame. Or, if it cannot, the reasons therefore are explained. This exercise ensures that everybody is aware of the current status of development and potential changes to the expected and agreed project outcomes.

Tracking design progress against goals can be done in different ways. Perhaps the most advanced approach to measure progress towards design goals is use of the scorecards for achieving LEED credentials (example on Figure 13). The Figure below shows an example of expected or anticipated

sustainability goals, reflected in the desired LEED score and an assessment of current design against performance targets. The same approach can be used to track progress towards other design goals.

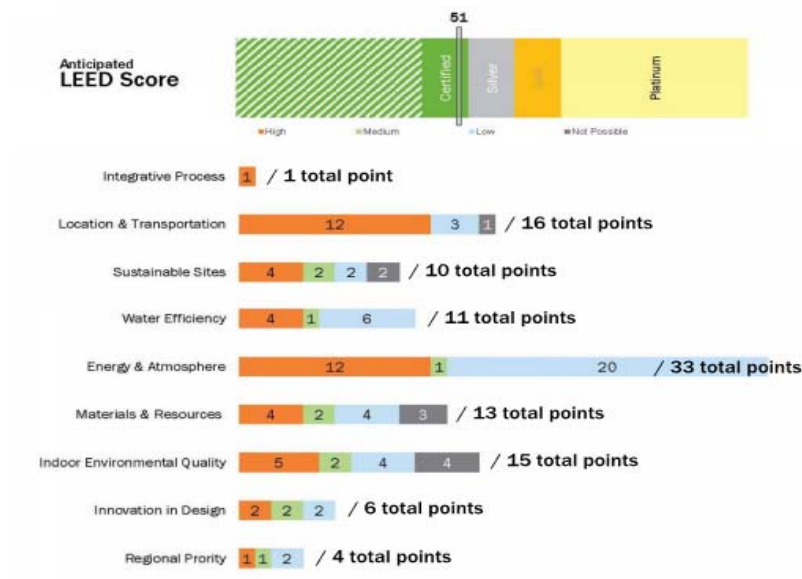


FIGURE 13: EXAMPLE OF SCORECARD TO ACHIEVE DESIGN SUSTAINABILITY GOALS

3.3 Value Management Maturity Matrix

The table below presents different levels of maturity while establishing methods and processes for effective Value Management. Observed practices and their expected effects are listed. This maturity matrix is intended to provide a quick guidance for teams that are seeking to establish effective Value Management practices (Figure 14).

| <i>Value Management</i> | | |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | <i>Practices</i> | <i>Effects</i> |
| <i>Level 4</i> | + Simulation techniques is used to support the creation of a shared understanding of building operations, use and activities as well as potential impacts to cost and schedule | + Stakeholders understand what they will get and when. They sign-off to demonstrate agreement as design progresses |
| | + Stakeholder meetings occur frequently in the big room. Not only for design consultation but also for progress report-out and other activities. | + Decision making process is streamlined – little rework |
| | + Design goals are clear, well defined and done holistically. Progress against those goals is tracked and demonstrated | + Team members understand and can explain the purpose of the building and its impact on society |
| <i>Level 3</i> | + Project team works together on an effort to align stakeholder expectations | + Stakeholders (users, permitting agents, donors, external players) understand the project vision, trade-offs in their choices and the consequences of their requests |
| | + Design goals are clear, and efforts are done to demonstrate progress well defined but progress is not demonstrated on a formalized approach, just communicated | + Project team understands well the criteria for satisfaction for each stakeholder |
| | + Pre-sign offs sessions for design review and stakeholder input | |
| <i>Level 2</i> | + Stakeholders are identified and engaged to provide input on design efforts. | |
| | + Meetings with stakeholders are well organized | + The purpose of the building and its impact on society is understood mainly by the design team |
| | + Sign-off is formalized | |
| <i>Level 1</i> | + Stakeholders are consulted periodically but are not engaged proactively on design efforts | + Rework is still observed due to unclear understanding of requirements |
| | | + Unmanaged expectations can cause significant impact on project costs and schedule |

FIGURE 14: VALUE GENERATION MATURITY MATRIX

4. Target Value Design (-Delivery)

4.1 Background

Target Value Delivery (TVD)⁷ is a supporting approach to generate value in construction projects. It helps teams to better understand project priorities, clarify constraints and monitor the realization of value throughout project delivery. Through TVD, project teams are able to analyze, compare, review, present and ultimately decide on the most advantageous solutions for the project, while fulfilling the holistic design goals (related to both the product and the production process). During construction, those targets are then monitored, to ensure their achievement.

Target Value Design and Target Value Delivery are currently used synonymously. However, Target Value Delivery is a suggested evolution of Target Value Design. The intent is to reflect the need to steer not only the design phase to targets, but also the construction phase. Steering construction to targets and monitoring progress against those targets will ensure value is realized.

The origins of TVD can be traced back to Target Costing (TC), a practice used in new product development and popular in the car manufacturing industry. One fundamental principle of this method is viewing cost as an input to the product development process, instead of an output. Coupling this principle with transparency and cost tracking, TVD supports integrated project teams to plan and manage production costs, delivering to the expected or greater performance targets while reducing production costs.

UCSF's main expectation regarding Target Value Delivery is to incentivize the reduction of overall project costs, including operations, and bring greater predictability to the costs associated with design and construction. As part of achieving that goal, UCSF expects to have active participation on the process and support the team with effective decision-making.

TVD encompasses three major phases: (a) setting targets, (b) steering project design (product and production process) to targets and (c) steering project execution to targets. It also brings key elements of lean design to support design development and decision-making: Set based design, Choosing By Advantages (CBA), Continuous Cost Estimating, and Cross-disciplinary effort for idea generation and implementation.

⁷ For more information on Target Value Design, please see Malcomber (2007) available at www.leanconstruction.org, Do et al. (2014), available at www.iglc.net/Papers

Target Value Design Principles

- *Rather than estimate cost based on a detailed design, design based on a detailed cost estimate;*
 - *Rather than evaluate the constructability of a design, design for what is constructible;*
 - *Rather than design alone and then come together for group reviews and decisions, work together to define the issues and produce decisions then design to those decisions;*
 - *Rather than narrow choices to proceed with design, carry solution sets far into the design process;*
 - *Rather than designing a product, design a product and its production system to make sure that the value proposition is realized*
 - *Rather than designing and assessing at the end, monitor value realization throughout project delivery.*
-

4.2 TVD Mechanisms

Five mechanisms are identified as effective to support collaboration on projects. Those are (Figure 15):



FIGURE 15: TARGET VALUE DELIVERY MECHANISMS

4.2.1 Understanding Constraints and Setting Targets

Prior to initiating any project, UCSF develops design guidelines, submits a business case and gets the financial preliminary approval from the University Regents. The University Regents establish a Maximum Allowable Cost (MAC) for the project. The MAC represents what the University is able and willing to pay for the whole project and within that amount there is an Allowable Cost for Construction. This information, together with the guidelines for design, is the starting point for TVD.

The Allowable Cost along with the *Design and Performance Criteria* will assist project teams to produce a validation study. The validation study allows the project team to calculate the estimated cost for the project (budget) based on current expectations for the project. This study also allows the team to compare current budget to actual costs of similar facilities and observe any gaps. If a gap is observed, the feasibility of

closing the gap is then analyzed. In this study, the estimates used to inform expected project costs should be transparent and accompanied with backup information.

The result of the validation study is the Target Cost. The Target Cost can be set below market comparison to spur innovation or to close the gap between allowable costs and market comparison (if necessary). The main function of the target cost is to challenge the team to deliver a solution that fulfills or exceeds the value proposition and performance targets for a lower construction cost.

4.2.2 Supporting cross disciplinary work

Once the value proposition is understood and the Target Cost is set, the second step of TVD is steering to targets during the design phase. As design progresses, the conceptual estimate will evolve into a more detailed estimate by building system. The project team is organized in multi-disciplinary clusters according to this structure. The intent of a cluster organization is to incentivize cross-disciplinary work and the generation of ideas that can contribute to achieving better design solutions (improved performance and reduced construction costs).

For each cluster, design goals are established based on the value proposition (program, design guidelines, systems performance), along with a maximum allowable cost and a target cost by cluster. This allows teams to better evaluate building systems and identify opportunities to improve performance and/or reduce costs. That includes analyzing and documenting opportunities and risks associated with programming, scope and performance goals, while working in a cross-disciplinary fashion to challenge and improve existing design solutions from a constructability standpoint.

Sometimes, teams also establish a production cluster. The role of the production cluster is to evaluate construction methods and techniques from an efficiency standpoint. That includes analyzing and documenting opportunities and risks associated with the construction phase, e.g., opportunities for engaging in early buy-out and pre-fabrication, challenging productivity assumptions, and understanding potential risks due to soil conditions, material and labor cost escalation, etc.

Independent on the cluster type, the success of these groups in generating and incorporating savings idea is dependent on the collaboration between who is designing and who is estimating. Estimators and designers should work hand in hand from early stages, analyzing the potential savings or potential impact that design alternatives might bring if approved and incorporated to the drawings.

4.2.3 Continuous cost estimating and Tracking

Continuous cost estimating is also referred to “over the shoulder” estimating, in which project teams work together to develop both design and estimate collaboratively. Instead of designing and then learning too late that the project is over budget, teams work together informing design decisions and steering the project to Target Cost. Continuous cost estimating should be coupled with cross-disciplinary idea generation to reduce the costs through innovation while maintaining the desired functionalities, capacities and quality. Examples of value engineering approaches may include:

- Changing the configuration of interior partitions to an alternative that presents an equal acoustic performance but can be produced at a lower cost
- Standardizing dimensions and modularizing ductwork so it reduces the costs of fabrication, and
- Modularizing and optimizing the use of glass panels so costs of fabrication are reduced

For keeping track of costs associated to design modifications, teams have used a TVD dashboard. The TVD dashboard contains information about the current estimate in comparison to the MAC and TC. The

estimate is generally divided according to the identified cost drivers, e.g., building design and construction costs; professional fees; owner related costs; escalation; and contingency. An example of TVD dashboard is shown on Figure 16.

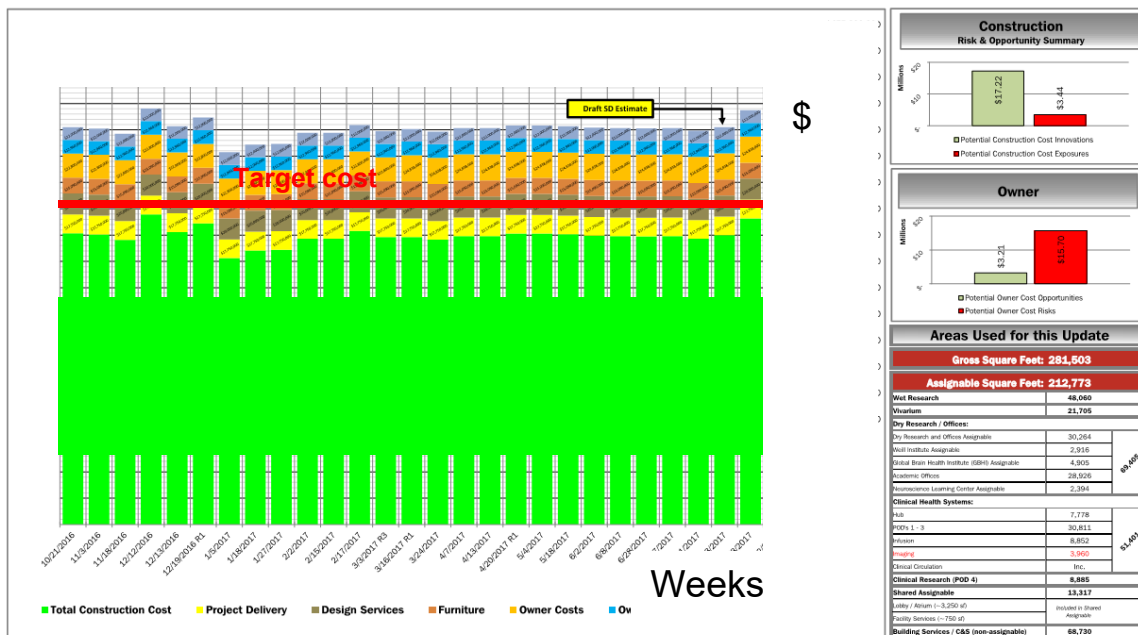


FIGURE 16: EXAMPLE OF TVD DASHBOARD.

4.2.4 Project Modification and Innovation Process

Clusters groups work collaboratively on a daily basis, and document their decisions through a Project Modification and Innovation Process (PMI). The PMI process was first introduced in the Med Center project and since then it has contributed for teams to reduce rework, assure that information about ideas are fully analyzed and that ideas are routed through the appropriate channels. According to a publication that used the Med Center project as a case study (Melo et al., 2015), 627 PMIs were proposed in that project. A total of 227 changes were approved and incorporated. Of the 227 PMIs that were approved, 196 PMIs involved only one party while 31 PMIs had two or more parties' involvement. Although only 31 out of the 227 PMIs involved more than one party, financially these PMIs accounted for approximately 45% of total construction cost savings. Presumably, the innovations with greater savings impact tend to involve multiple disciplines and building systems.

In the core of the PMI process lays a Risk and Opportunity (R&O) analysis. The R&O worksheet developed by the B23A team (snapshot below) includes a throughout analysis of ideas before they are incorporated as a change. The analysis include: (a) overall cost, quality and schedule impact; (b) potential impact to other clusters; (c) resulting changes (enhancement or negative impact) in regards to maintainability, sustainability, operability, aesthetics, constructability, ability to pre-fabricate, etc.

FIGURE 17: EXAMPLE OF TEMPLATE FOR ROUTING DESIGN IDEAS.

The PMI will generate information that is kept on a R&O log. The R&O log should be updated on a weekly basis, discussed and approved at the Project Team meeting. Once reviewed, the R&O log will feed the TVD dashboard, which should be updated on a regular basis.

4.2.5 Set-based Design and Choosing by Advantages

Set-based design⁸ is an alternative to the traditional point-based design approach, in which one single design solution is chosen upfront to be refined. In set-based design, decisions are delayed to allow multiple alternatives to be developed. A set of alternatives is gradually narrowed down by eliminating inferior options until a satisfactory solution emerges. Understanding the Last Responsible Moment (LRM) already mentioned in session 3.3.2 is key when applying set-based design.

Set based design can be supported by a Choosing by Advantages (CBA) decision-making technique. Choosing by Advantages supports sound decision-making by using specific comparisons among the advantages of each alternative. In order to make such comparisons, teams must determine and agree on the factors that will be considered for judging the alternatives and then gather information about the attributes that each alternative offers. The selection will be based on the analysis of attributes and the advantage that they bring to each alternative. This exercise helps teams to reach consensus on how to judge the multiple design options and make decisions based on real data.

Three steps are required to develop a CBA analysis (Figure 18): (a) define the scope of solutions by understanding satisfaction criteria; (b) develop a set of alternatives that meet the satisfaction criteria; and (c) present alternatives in a concise way (A3 format – 11" x 17") to support decision-making.

⁸ For more on set-based design, see Parrish et al. (2007) and for a step by step example on how to apply CBA, please see Parrish and Tommelein (2009). Both available at www.iglc.net.

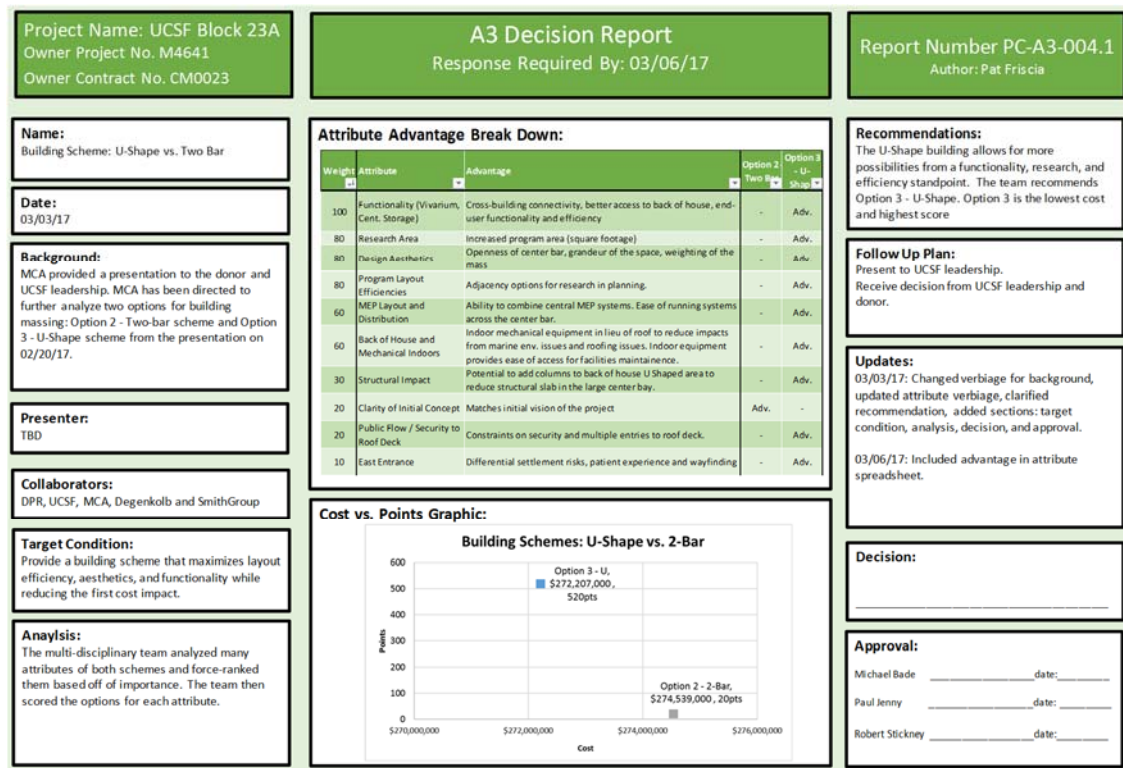


FIGURE 18: EXAMPLE OF CBA FOR SELECTING A PREFERRED DESIGN ALTERNATIVE.

As the team approaches the construction phase, the ideas to decrease field labor hours are put in place and the team monitors their performance through construction. Monitoring progress and productivity targets allows teams to observe deviations and take action to improve project outcomes proactively. A disciplined approach to monitoring and implementing countermeasures has been observed to contribute to better project outcomes.

At this stage, the same techniques explained on sessions 4.2.3, 4.2.4 and 4.2.5 can be used to support the decision making process. Some teams have successfully linked tracking of production costs with the last planner system and other approaches for production tracking and control. Linking techniques to manage schedule and production costs allow teams to have a quicker feedback and be more proactive in the implementation of countermeasures.

Shared savings generally results from a cross-disciplinary effort to generate ideas to reduce costs of production and fabrication. Those savings are realized during pre-construction (i.e. buy out strategies) or during the construction period, when expected savings from more efficient ways of building may be realized. Those savings must be monitored and documented periodically by a comparison between expected costs and actual costs associated with production.

4.3 Target Value Design (-Delivery) Maturity Matrix

The table below presents different levels of maturity while establishing methods and processes for TVD. Observed practices and their expected effects are listed. This maturity matrix is intended to provide a quick guidance for teams that are seeking to establish practices that can effectively support TVD (Figure 19).

| <i>Target Value Design (-Delivery)</i> | | |
|----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | <i>Practices</i> | <i>Effects</i> |
| Level 4 | <ul style="list-style-type: none"> + VE workshops are multidisciplinary, include shifts in scope and money between companies and focus on reducing production and fabrication costs + Close control of fabrication and production cost with proactive approach to savings opportunities + 5D supports cost tracking and control | <ul style="list-style-type: none"> + Savings from reduced production and fabrication costs are realized and celebrated during construction + Majority of savings opportunities is originated from cross-disciplinary collaboration targeted to reduce production and fabrication costs |
| Level 3 | <ul style="list-style-type: none"> + Team helps stakeholders to understand the implications of their requests and the possibilities within project constraints + Teams have a streamlined approach for managing and including ideas on risk and opportunity log + Risk and opportunity log is created by the clusters and evaluated on a weekly basis + Multiple alternatives are analyzed and their advantages compared (set based design) + Design decisions are memorialized - on CBA or A3 templates | <ul style="list-style-type: none"> + Designers, builders, owner and stakeholders have a sense of responsibility for reconciling expectations with project constraints + “Real time” (weekly) cost updates with design updates + Budget allocations are moved freely across clusters to meet project target budget |
| Level 2 | <ul style="list-style-type: none"> + A TVD dashboard is updated monthly + Production and fabrication costs is considered a criteria for coming up with design alternatives + Benchmarks are used to validate project estimates | <ul style="list-style-type: none"> + No major investment in design is done without prior analysis of design alternative implications + Project estimated costs are agreed upon – the team undertakes a reconciliation process if necessary between scope, expected performance and costs |
| Level 1 | <ul style="list-style-type: none"> + Project budget analyzed and validated by team + Full budget transparency supports conversations from day one | <ul style="list-style-type: none"> + Even though reconciliation of budget and scope may not have occurred yet, the elements within the budget are fully understood by different parties and treated with full transparency |

FIGURE 19: TARGET VALUE DESIGN (-DELIVERY) MATURITY MATRIX

5. Elimination of Waste and Rework

5.1 Background

The elimination of waste and activities that do not add value to achieve the project goals is another core element of the lean philosophy. Waste can be understood as⁹:

- Waiting – for materials, for design information or specifications, for others to finish their part of a job, for inspection and/or signoff.
- Overproduction – Producing more of something than is actually required by the customer, or working on items out of sequence in such a way that they may need to be reworked later.
- Defects and Rework – Any job or portion of a job which doesn't conform to specifications or doesn't meet quality standards and has to be rebuilt.
- Motion – Excessive movement of people around the site, excessive steps to perform tasks are forms of waste (of time and productive capacity).
- Transportation – Likewise, excessively moving materials, tools and equipment around the site is a form of waste.
- Over Processing – Producing work to a specification higher than what is needed for the job.
- Inventory – Too much inventory or too little. If too much, the inventory physically impedes the flow of work and has to be moved out of the way (transportation waste); if too little the smooth flow of materials into the job is interrupted (waiting waste).

Elimination of Waste and Rework Principles

- *Eliminating waste requires seeing it first. Measurements are a means of creating awareness about waste, while standardized works helps us identifying it faster*
 - *Optimize the whole not the parts by focusing not only on the transformation process but on how the work flows between different operations*
 - *Focus on root cause of problems to find solutions that are sustained*
 - *Tools are only as good as the discipline created around its use*
-

⁹ Definition based on P2SL glossary, available at: <http://p2sl.berkeley.edu/glossary/>. For more on waste and rework in the construction industry, see for instance Koskela (2004) and Viana et al. (2012), both available at www.iglc.net.

5.2 Elimination of Waste & Rework Mechanisms



FIGURE 20: ELIMINATION OF WASTE AND REWORK MECHANISMS

5.2.1 Standardized work

Standardized work in construction projects can be introduced by means of designing the production system¹⁰. Production system design extends from global organization to the design of operations; e.g., from decisions regarding who is to be involved in what roles to decisions regarding how the physical work will be accomplished. The design of the production system should include not only transformation processes but also flow. Considering how material and information flows is paramount for achieving continuous flow and predictability in the job site. It encompasses defining a production strategy that supports continuous workflow. The goal of a production strategy is to analyze the areas of production and define the sequence and flow of activities that best supports stability and predictability. How that strategy will be supported with the right materials, information to achieve stable and predictable workflow.

In addition, standardizing work supports increased productivity within overall workflow by having an agreed-upon best practice for each specific work task. Standardizing work is the foundation for continuous improvement, and also confers the benefit of allowing processes to be balanced and ensure that no-one is overloaded or under-utilized. The workers themselves have the responsibility for standardizing their own work by recording the safest and best way to achieve the desired quality outcomes in the most efficient manner.

Standardized work is a powerful tool for achieving quality standards, smoothing variability in workflow, and creating dependable task relationships and durations. It consists of three basic elements:

- A well-defined production strategy (based on continuous workflow) and a production system designed with parameters that support continuous workflow (i.e. takt planning)¹¹;
- The precise work sequence in which an operator performs tasks within the chosen production parameters;
- Inventory control, including units in production, required to keep the process operating smoothly.

5.2.2 Just in time

¹⁰ For an example of a comprehensive production system design, see Ibrahim, 2017.

¹¹ For more research and examples on takt planning, see: Frandson et al. 2013; Frandson and Tommelein 2016; Tommelein 2017.

Standardized work supports a just in time approach. Just in time is a system for producing or delivering the right amount of parts or product at the time it is needed for production ("JIT"). A JIT system produces only what is needed, when it is needed, and in the amount needed – no more, no less. In doing so, JIT is inherently a pull system (as opposed to push) that responds to actual customer demand, committing only the resources needed to fulfill the customer's needs. This, in turn, leads to reduced inventory, enhanced human productivity, better equipment utilization, shorter lead times, fewer errors, and higher morale.

Just-in-Time logistics (including logistics of delivery of information as well as of materials) helps avoid the following forms of waste: waiting, motion, transportation, inventory and rework.

5.2.3 Built in Quality and Poka-Yoke

Built in Quality (BiQ) is created through the careful design of operations so as to prepare workers to execute work with no defects or rework. Strategies include not only designing operations in detail but also performing successive inspections during operational steps and at each hand-off. BiQ aims to avoid the reliance on end-of-line inspection and correction to achieve conformance to requirements¹².

Built in Quality is a powerful strategy for avoiding rework and quality problems. Introducing BiQ requires both GC and trades to work together focusing on prevention and early detection and correction of defects. The following methods can support the adoption of BiQ in practice:

- Understanding acceptance criteria. Perhaps the most powerful strategy to get quality right the first time is to understand the acceptance criteria for a work package. Understanding acceptance criteria starts in the design stage, where stakeholder requirements should be discussed and the acceptance criteria established.
- Prototyping. Another way to assure quality at the source is designing and testing products (i.e. mockups) and processes (i.e. first run studies). Prototypes can be either physical or digital and they allow key players to visualize and agree on their expectations regarding a product feature of a production process.
- Use of Poka Yoke¹³. Poka Yoke is a Japanese term for mistake-proofing a method or device. The concept was developed to prevent an error or defect from happening or being passed on to the next operation in a production sequence. Mistake proofing requires a different way of thinking about production processes and their constituent operations. It requires the consideration of innovative ways to design work that reduces the risk of installation errors. Restricting the way two components can be attached by manipulating their geometry is a way of using poka yoke.
- A no blaming culture. A blaming culture can highly contribute for quality issues not being detected or revealed upfront. Project teams are encouraged to develop a safe environment that stimulates those people doing the work to bring up issues as they see it so that any quality deviation is caught early.
- Reducing batch sizes. Small batch production helps in earlier identification of defects.
- Self-inspection and inspection at hand-offs prevents defects from moving downstream the production line¹⁴.

¹² For more on BiQ please see: Tommelein and Ballard (2014).

¹³ For more on poka yoke in construction, please see Tommelein (2008) available at www.iglc.net

¹⁴ For examples on integrated inspection between site and fabrication facility, please see Alves et al. (2013)

- 'Stopping the line' when a defect is detected rather than releasing bad product past your production unit. This may be done by the direct worker or his/her immediate supervisor.

5.2.4 5S and Visual Management

5s is a class of activities undertaken to maintain the workplace in good order so that work can be accomplished efficiently and with good morale. The organization of the workplace reflects upon the work being done there and communicates values to the people working there. The five S's are:

- **Sort** (making sure that sufficient materials and the proper tools are at hand to accomplish the work, but not more than is needed);
- **Set** (how to organize the worksite so that needed materials, tools, and equipment are in the best and safest locations);
- **Shine** (maintaining the worksite cleanly and in good order);
- **Standardize** (achieving within the team the standard to which the workplace will be kept, photographing it and displaying the photographs so that all are clear on how the jobsite should be kept up); and
- **Sustain** (the work that project or program leadership must undertake to communicate standards to everyone, and the expectations that these will be met).

Visual Management is an important component of sustaining the organization provided by applying 5s. Placing tools, parts, production activities, plans, schedules, measures and performance indicators in plain view assures that the status of the system can be understood at a glance by everyone involved and actions taken locally in support of system objectives. 5S activities and visual management address a range of risks created by sloppy jobsite organization, poor or lackadaisical communications with the workforce, and unstandardized work.

5.3 Elimination of Waste & Rework Maturity Matrix

The table below presents different levels of maturity while establishing an Environment, in which team members are vigilant of waste and work together on mitigating their sources. Observed practices and their expected effects are listed. This maturity matrix is intended to provide a quick guidance for teams that are seeking to establish an effective Waste & Rework Mitigation Environment (Figure 21).

| <i>Collaborative Project Delivery</i> | |
|---------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | <div>Practices</div> <div>Effects</div> |
| Level 4 | <div> <ul style="list-style-type: none"> + All project participants practice waste elimination and prevention through project delivery + Logistics planning is extended to supply chain + Waste reduction efforts include also design and not only construction </div> <div> <ul style="list-style-type: none"> + Savings and efficiencies are seen from ongoing and integrated work to eliminate waste + Visual management with up to date KPIs supports both construction and design teams + Indicators such as quality of RFIs and Submittals are established + The whole project team is vigilant and skilled in eliminating and reducing waste and increasing efficiency </div> |
| Level 3 | <div> <ul style="list-style-type: none"> + Training is offered on waste and lean tools and techniques such as BiQ, 5S, takt-time, first-run studies + 5S efforts and visual dashboards are easily maintained and kept up to date + Examples of BiQ are found + Inspectors are engaged proactively and are part of the team (i.e LPS) </div> <div> <ul style="list-style-type: none"> + Visitors regularly remark on exceptionally clean and orderly sites + Schedule gains + All field personnel feels responsible for contributing to executing and improving the production strategy + Increased morale, safety and productivity + No quality problems </div> |
| Level 2 | <div> <ul style="list-style-type: none"> + Trades are engaged in improving the design of field operations + There is a robust quality program in place + A production strategy is defined and agreed by all field personnel </div> <div> <ul style="list-style-type: none"> + Waste is a topic of investigation or discussion in production planning and control for various building disciplines + Quality is seen as an integral part of production planning </div> |
| Level 1 | <div> <ul style="list-style-type: none"> + Constructability reviews and design of operations is done to identify sources of waste but not on a participatory and integrated approach + Some people have awareness of what waste is but there is not a collective effort around identifying and minimizing waste </div> <div> <ul style="list-style-type: none"> + Waste is sometimes a topic of investigation or discussion in production planning and control </div> |

FIGURE 21: ELIMINATION OF WASTE AND REWORK MATURITY MATRIX

6. Last Planner System

6.1 Background

The Last Planner System (LPS) is a collaborative planning process that involves field supervisors or design team leaders (the last planners) planning in greater and greater detail as the time for the work to be done gets closer. LPS was created to enable more reliable and predictable production both in the design and execution phase of projects. It:

- Supports the flow of work through the project
- Builds trust and collaboration
- Helps deliver projects safer and faster

LPS was developed in the early 1990s by Glenn Ballard and Greg Howell. Their motivation was the observation of a large discrepancy between field activities planned based on a master schedule and the actual work being done. Actual measurements revealed that what actually gets done in terms of planned activities averages 54%. The reason for that, they explain, is that master schedules inform the work that 'should' be done. However, the conditions in the field vary and such variation does not allow for plans to be 100% executed as expected. *"There is simply a mismatch between what we should do and what we actually can do in the field"* – Glenn Ballard¹⁵.

Since the early 1990s much has advanced regarding the practical adoption of LPS. Nowadays, LPS is not only used to coordinate field activities, but also to support better workflow during the design phase. Advances in technology have also contributed for supporting LPS implementation with different software solutions. Also, the adoption of 3D modeling and 4D scheduling has contributed to better visualization of work, providing greater support for coordinating work activities.

Since 2008, the last planner system has benefitted UCSF projects in the following ways:

- LPS has contributed to achieving better schedule outcomes
- LPS has allowed us to better understand when we need to make decisions to support the project teams
- LPS increases communication and information sharing, and contributes to team members making reliable commitments to one another and therefore increases predictability of outcomes.

UCSF's main expectations regarding Last Planner System is to incentivize the reduction of the overall schedule duration and bring greater predictability to project delivery time. As part of achieving that goal, UCSF expects to have active participation in the system to understand when action from our multiple internal stakeholders is required, e.g., when decisions need to be made, when plans need to be reviewed and approved, when inspections need to be conducted, etc.

¹⁵ Many papers, benchmarks, guides and procedures have been published describing the system. Reference material can be found at LCI's database <https://www.leanconstruction.org/> and IGLC database at: <http://iglc.net/Papers>. Ballard and Tommelein (2016), for instance, offer a current benchmark on the LPS.

Last Planner System Principles

- *Plan in greater detail only as you get closer to doing the work.*
 - *Produce plans collaboratively with those who will do the work.*
 - *Reveal and remove constraints as a team.*
 - *Make and secure reliable promises.*
 - *Learn from breakdowns.*
 - *Maintain a workable backlog as a buffer*
-

6.2 LPS Mechanisms

Six main components form the LPS. Their intent is to improve workflow reliability and improve the match between plan and execution of work. Those are:



FIGURE 22: LAST PLANNER SYSTEM MECHANISMS

6.2.1 Phase (Pull) schedule specifying handoffs

In the master schedule, major milestones, overall production strategy and long lead-time items are identified. As this is a long-term plan, it should be kept at a milestone level, to be progressively detailed phase by phase, collaboratively using pull planning with those who are to do the work in each phase. The master schedule specifies the dates that work milestones must be achieved.

Creating a pull schedule is different than creating a schedule based on a forecast. Pull schedule is a method of planning collaboratively with those who are to do the work being planned. Its main purpose is to specify handoffs between participants. The resulting pull schedule shows the interdependency of tasks among different participants, clarifying the specific handoffs.

6.2.2 Look ahead plan to make activities ready

Increased labor productivity does not necessarily result in better schedule performance. To improve schedule performance, the right activities need to be done and need to be ready for execution at the right time. In the look ahead planning, activities 3-6 weeks out are screened and made ready for execution. Making an activity ready means removing any constraints or roadblocks for its execution, e.g. missing equipment, material, and drawings.

An important companion to the look-ahead plan is the constraint log. The constraint log helps teams keep track of the status of constraints relevant to upcoming field operations. It also allows assigning people responsible for removing those constraints on time so field operations are not impacted.

6.2.3 Weekly Work Plans and Daily huddles

Weekly meetings and weekly work plans allow teams to prepare for the following week's work and review what was accomplished the previous week. The focus of a weekly work plan is making sure activities are well defined, well sequenced, within the capacity of those doing the work, and free of constraints. As a result, the amount of work completed better matches the amount of work planned and productivity increases.

Effective weekly work planning requires that each Project Team member clearly communicates its needs and must provide reliable promises to other members with regard to its own performance. A reliable promise is a key component of the last planner system (often referred to as commitment based planning). If a Team member discovers that it will not achieve a promise, it must immediately inform the Project Team identifying when it can perform, and any impediments to its performance.

6.2.4 Production dashboards and learning

Production dashboards (Figure 22) have the purpose of measuring the performance of the planning system to support continuous improvement. It is the least implemented but one of the most important elements of the Last Planner System. By analyzing current performance, teams can identify opportunities for improvement and implement countermeasures to create a more productive work environment.

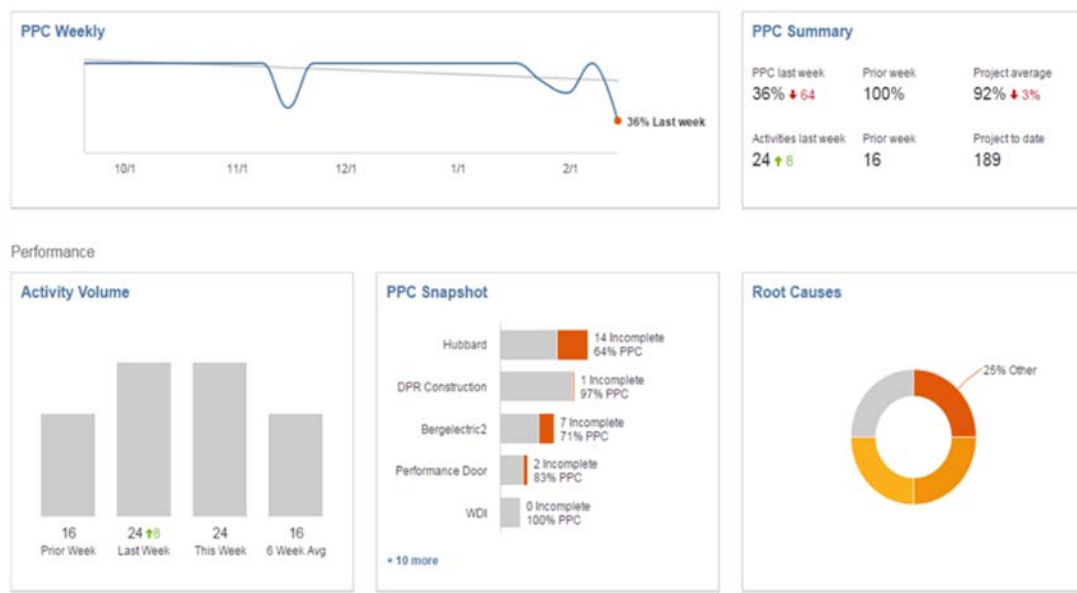


FIGURE 22: EXAMPLE OF PRODUCTION DASHBOARD

6.3 Last Planner System Maturity Matrix

The table below presents different levels of maturity while implementing the Last Planner System. Observed practices and their expected effects are listed. This maturity matrix is intended to provide a quick guidance for teams that are seeking to effectively implement LPS (Figure 23).

| <i>Last Planner System</i> | | |
|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | <i>Practices</i> | <i>Effects</i> |
| Level 4 | <ul style="list-style-type: none"> + BIM is utilized to support last planners participation on production planning and control + Team uses survey or other feedback tools to assess and improve the impact of LPS | <ul style="list-style-type: none"> + Activities are well coordinated, productivity and morale are high + Team works together to identify and remove constraints + 3D modelling becomes fundamental to support and explain the production strategy |
| Level 3 | <ul style="list-style-type: none"> + On-boarding and training is provided to last planners when they join the project + LPS concepts are used to support both design and construction + KPIs are displayed publicly and/or discussed on a regular basis | <ul style="list-style-type: none"> + Team members (both design and construction) refer to LPS and related terminology “reliable promise”, “last responsible moment”, “commitment”, etc. + Productivity improvements are observed |
| Level 2 | <ul style="list-style-type: none"> + LPS supports field coordination and the integration between design and construction (support to field operations) + All field supervisors are active participants on LPS | <ul style="list-style-type: none"> + Field activities are well coordinated, Project managers from different companies are engaged in supporting their crews to remove constraints before executing the work + There is good cadence of meetings, discipline and consistency on the application of LPS |
| Level 1 | <ul style="list-style-type: none"> + Team uses pull plan sessions to organize their work + Weekly work plans are generated with input - and distributed to - field supervisors | <ul style="list-style-type: none"> + Despite the fact that constraints may not be removed on time, field activities are well coordinated among supervisors |

FIGURE 23: LAST PLANNER SYSTEM MATURITY MATRIX

7. Key performance indicators

The table below contains a list of suggested KPIs that are related to lean practices. The goals on this table were set based on current projects and are for illustration only. Goals, along with the relevant KPIs to use should be discussed and agreed by the project team.

| <i>Area</i> | <i>Indicator</i> | <i>Measurement</i> | <i>Frequency</i> | <i>Goals</i> |
|-------------------------------------------------|------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|------------------|--------------------|
| <i>Collaborative Project Delivery</i> | <i>Team's pulse check (survey)</i> | <i>Surveys received back / total submitted</i> | <i>Monthly</i> | <i>>70%</i> |
| | <i>Communication</i> | <i>N of Confirming RFIs / Total N of RFIs submitted</i> | <i>Monthly</i> | <i>>90%</i> |
| | <i>Communication</i> | <i>N of Submittals approved on 1st submission / Total N of Submittals</i> | <i>Monthly</i> | <i>>90%</i> |
| | <i>Continuous improvement</i> | <i>N of ideas generated and implemented</i> | <i>Monthly</i> | <i>3 items</i> |
| <i>Value Management</i> | <i>Customer satisfaction (survey)</i> | <i>% of stakeholders satisfied with project design and engagement in project</i> | <i>Monthly</i> | <i>>70%</i> |
| | <i>Programmatic requirements</i> | <i>Actual Assignable SQFT - Minimum Assignable SQFT Actual Gross SQFT - Minimum Gross SQFT</i> | <i>Monthly</i> | <i>>0</i> |
| | <i>Building performance</i> | <i>Building actual vs. target performance. Example: Sustainability, Resilience, Maintainability, Occupant/visitor experience, Cost of ownership</i> | <i>Monthly</i> | <i>TBD</i> |
| <i>Target Value Design (- Delivery)</i> | <i>Total project estimate vs. MAC</i> | <i>Overall actual estimated costs - MAC</i> | <i>Weekly</i> | <i><0</i> |
| | <i>Construction estimate vs. MAC</i> | <i>Overall actual construction estimated costs - MAC</i> | <i>Monthly</i> | <i><0</i> |
| | <i>Variance estimated vs. target cost by cluster</i> | <i>Cluster actual estimated costs – maximum cluster cost</i> | <i>Weekly</i> | <i><0</i> |
| | <i>Contingency balance</i> | <i>Remaining contractor's contingency at end of each phase</i> | <i>Monthly</i> | <i>>2%</i> |
| <i>Elimination of waste and rework</i> | <i>RFI status</i> | <i>RFI turnaround time (days)</i> | <i>Monthly</i> | <i><10 days</i> |
| | <i>Submittal status</i> | <i>Submittals turnaround time (days)</i> | <i>Monthly</i> | <i><30 days</i> |
| | <i>Inspector pass rate</i> | <i>Passed inspections vs. planned inspections</i> | <i>Monthly</i> | <i>100%</i> |
| | <i>Re-inspection resolution</i> | <i>Time to resolve outstanding issues (days)</i> | <i>Monthly</i> | <i>< 3 days</i> |
| <i>Last Planner System</i> | <i>Plan Percent Complete</i> | <i>N of tasks completed on the week / tasks planned</i> | <i>Weekly</i> | <i>>70%</i> |
| | <i>Tasks made ready</i> | <i>N of tasks made ready on the look ahead / tasks planned</i> | <i>Weekly</i> | <i>>70%</i> |
| | <i>Schedule savings per milestone phase</i> | <i>N of days saved on milestone schedule in %</i> | <i>Monthly</i> | <i>>3%</i> |
| | <i>Labor Increased Productivity</i> | <i>Actual labor hours - planned labor hours</i> | <i>Monthly</i> | <i>>10%</i> |

FIGURE 24: SUGGESTED KEY PERFORMANCE INDICATORS

8. References and Resources

8.1 Resources

Lean Construction Institute's database <https://www.leanconstruction.org/>

International Group of Lean Construction database <http://iglc.net/Papers>.

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