CS22159

Integrating Project Delivery

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Learning Objectives

1. Understand how BIM and simulation supports design for sustainable, high performance buildings
2. Understand BIM as a foundation for designing to performance targets within the time and money available]
3. Understand how BIM field applications support high quality, Lean construction
4. Understand how to use technology to strengthen collaboration and integrated design

Description

This industry talk will focus on a new perspective on Integrated Project Delivery (IPD) in which the strategies for organization; work methods and processes, and information management are derived from the value created through design and construction of a valuable, high performance building.

A high performing building can only be achieved through a building with integrated building systems, which can only be produced through an integrated process, which depends on an integrated team with the right people, which needs integrated information, i.e., BIM+ to function effectively and efficiently. Simulation and visualization are the primary ways in which BIM+ informs the integrated team. Collaboration and co-location are the primary ways that allow the integrated team to integrate processes. Production management methods enable the productive design, fabrication, and construction of the integrated building system. Outcome metrics define the performance of the building and validate the integrated building system. All of this is supported by the appropriate agreement or framework.

Your AU Experts

Dean Reed

Dean Reed has seen a lot in his 43 years in construction after graduating with a Bachelors Degree in Psychology from the University of California Santa Cruz and serving in the U.S. Peace Corps. His perspective changed dramatically in 1996 when he discovered Lean Construction and Virtual Design & Construction (VDC) together. He brought that new thinking to DPR Construction when he began working there as a project planner in 1997. Since that time, Dean has worked tirelessly to help DPR people, and owners, designers and trade partners understand and leverage their creative talents to deliver significantly better buildings. He is widely respected within the Lean Construction community in the U.S. and internationally. Dean often speaks at industry events and lectures regularly at Stanford University. He is a co-author of the forthcoming John Wiley & Sons book, *Integrating Project Delivery*, available March 27, 2017. Dean can be reached at deanr@dpr.com

John Wiegand

John Wiegand is a Senior Autodesk BIM 360 Implementation Consultant with the mission to help professionals understand the real-world application of Autodesk solutions for the construction community [including BIM 360 Docs, BIM 360 Glue and BIM 360 Field]. He is a LEED accredited professional with 33 years of construction management experience. John joined Autodesk to continue to engage in coaching LEAN construction principles and commitment-based planning and scheduling. His focus is on multiple fronts: Milestone Alignment Planning [MAP] coordination of schedules, production planning and commitment cycles; continuing to provide construction professionals with techniques to develop strategies to help make collaboration a priority in the field; promoting goal oriented processes with deliverable quality and timeliness; and analyzing opportunities for the improvement in production and planning of construction project life cycle practices. He can be reached at john.wiegand@autodesk.com

Introduction

This AU presentation is base on material from the forthcoming book, *Integrating Project Delivery*, to be published by John Wiley & Sons, and available March 27, 2017. The following text, and figures not credited to others, are © 2016 by Martin Fischer of Stanford University, Howard Ashcraft of Hanson Bridgett LLP, and Dean Reed and Atul Khanzode of DPR Construction. In their book, the authors explain how valuable, high performing buildings can be created using what they call, "A Simple Framework for Integrating Project Delivery," taking that goal as the starting point. Figure 1 shows the book cover composed from the SmithGroup JJR's illustration of the bioclimatic strategy for DPR Construction's Net Zero Energy (NZE) office in Phoenix, AZ. Below that is a night photo of the photovoltaic panels supplying electric power in the foreground atop covered parking adjacent to the East elevation's green-screen, and the 4-shower towers cooling outside air as it is drawn through window louvers by a solar chimney, all of which are controlled by a sophisticated Building Management System (BMS).

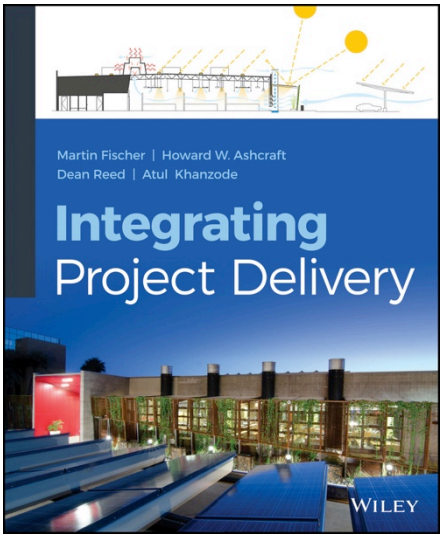

FIGURE 1. BOOK COVER.

Success Requires Four Tasks

There are four tasks every project team must do well to succeed: lead, coordinate, decide and do the right work at the right time, correctly. At the end of the day, a team gets paid for value-added work. Doing only or mostly value adding work requires coordination, leadership, and decisions – otherwise it's unlikely that each team member and all the sub-teams will carry out the work and work processes needed to produce a high-performing facility with integrated systems. Team members with the most experience and responsibility must create a new culture and organization. This includes setting up the coordination scopes and mechanisms and helping team members and owner stakeholders determine which decisions must be made, when and how to advance toward the project goals, etc. These same leaders help team members decide on their next steps.

The Current Reality

Because team members in non-IPD projects do not win or lose together, but by themselves, individual leaders must first think about how a decision affects their budget, schedule and bottom line, and maybe, if it doesn't cost anything, the project. Team members make sure their work is internally coordinated and sequenced before thinking about the project. Leaders and team members must make must make sure their company's interests are protected in making decisions, and then try to do what's best for the project. The imperative to first take care of each participating organization's interest results in having to re-do work because it does not meet the needs of other team members and the project as a whole. This rework is accepted as the normal course of business and not seen for the waste that it is. No one really knows how much there is because the rework is invisible. The rework consumes the time of valuable human resources and certainly adds cost to projects. Figure 2 shows the result of organizing this way.

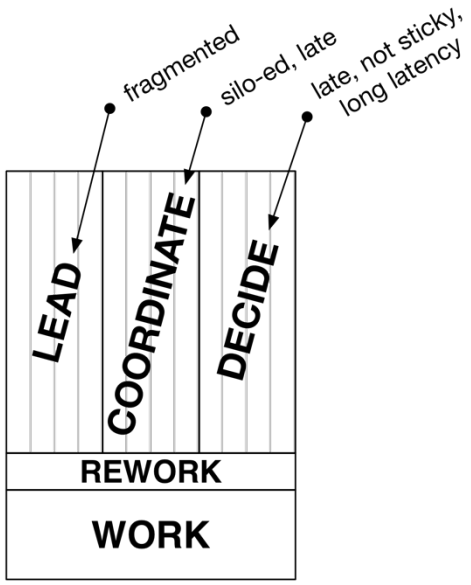

FIGURE 2. FRAGMENTED DELIVERY.

The Simple Framework for Integrating Project Delivery

The Simple Framework is best understood by working backwards from the product, which integrated project teams have agreed to deliver. A "high-performance building" must be useful to or usable by its occupants, it must be buildable safely within the time and money budgets available, it must be operable so that the building managers can create the right environment for the occupants with a commensurate expense, and finally, a building must be sustainable in its economic, environmental, and social context. A high-performance building is able to demonstrate that it meets the values and objectives stated by the owner at the beginning of the project, using specific metrics developed to evaluate its achievement.

A high-performance building is comprised of highly integrated systems, where systems are designed to work together and complement each other. To work together effectively, teams must have a way of communicating reliably and efficiently. "Integrated information," which supports simulation and visualization, and the easy access to that information, are used heavily to create a transparent and integrated process, in which all members of the team understand the work at all times. Simulations and visualization enable team members to share their knowledge effectively, to experiment, test and evaluate their ideas, to compare good solutions to poor solutions, and to communicate with other team members and stakeholders. Meaningful metrics, not simply data collected for the sake of having numbers in a chart, must be used both to track how well a team is performing, and how closely the building conforms to the goals and values of the owner. Metrics are essential to understanding and improving team performance during the process.

Upholding the entire IPD system is a contractual agreement and framework, which sets the "ground rules" for the project, and reinforces the idea that decisions can and must be made for the good of the project, not just for individual benefit. The contract will encourage and enable an integrated delivery system, and allow organizations and individuals to share information, collaborate, innovate, and challenge each other without fear of retribution.

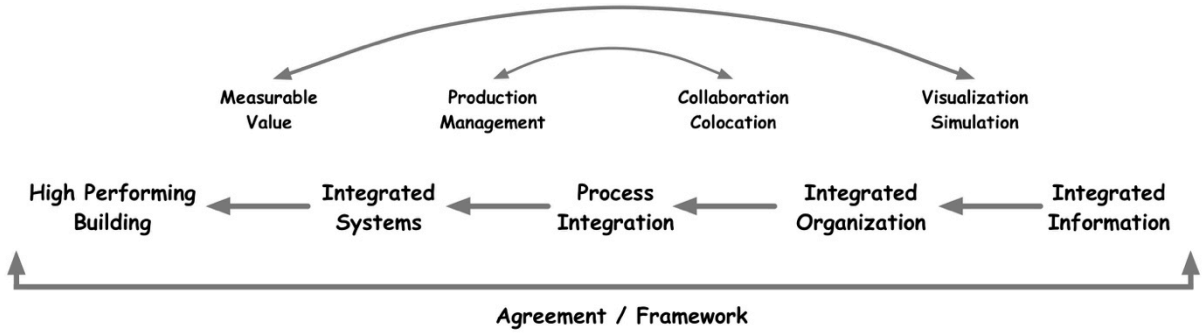

FIGURE 3. THE SIMPLE FRAMEWORK FOR INTEGRATING PROJECT DELIVERY.

The Supporting Agreement / Framework

The Simple Framework sits on the foundation created by a contractual agreement in which all the parties share in the risk and reward for the project. Achieving specific and better outcomes is the purpose of the IPD Contract. The process of defining a structure starts with determining the outcomes to be achieved, deciding which behaviors and processes are necessary to achieve the outcomes, factoring limitations that are imposed on the contract and then designing a structure. In this process, structure is the servant of outcome.

In the influence diagram shown in Figure 4, the project outcome requires some blend of the behaviors, shown as ovals. These behaviors are encouraged and shaped by the five key structural elements linked to them. In a full IPD Contract, all five structural elements are present and harmonized to the project objectives.

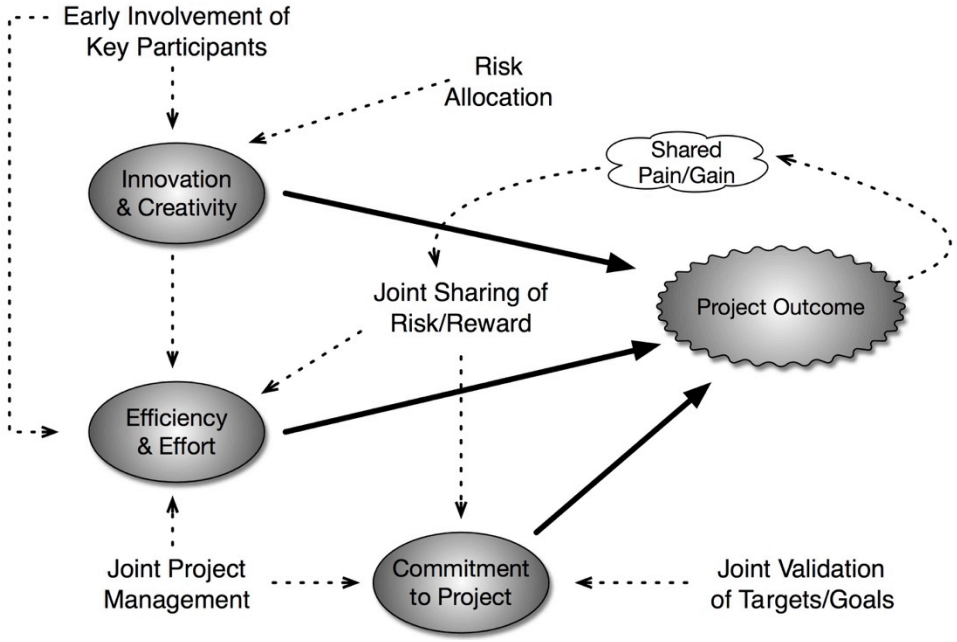

FIGURE 4: IPD ELEMENTS AND OUTCOMES. © HOWARD ASHCRAFT.

Four Criteria for a High Performing Building

We look at building performance through the eyes of the four main stakeholder groups in a building. In chronological order of building delivery, they are the design and build team, the professionals operating the building, the users of the building, and the managers of the building users who need to sustain their business. That's why we define performance of a building in these four categories: buildability, operability, usability, and sustainability, shown in Figure 5.

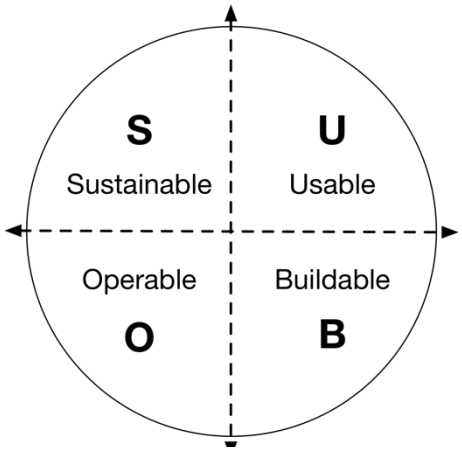

FIGURE 5. HIGH PERFORMING BUILDING CRITERIA.

High performance is about the whole package. It is the idea that a facility can be resource efficient, environmentally responsible in construction and operation, comfortable and safe for its occupants, easy and cost-effective to maintain, and allows its users to perform at their highest level. In short, a truly high performance building satisfies everyone who designs, constructs, operates, and uses a building as much as possible; it is a building everyone can be proud of.

Making Value Possible

A high performance facility enables its users to create the value they must deliver to thrive in their own business. For example, a bridge allows a certain number of cars to cross each day helping a transportation agency meet its goal of enabling people to go places; a school building allows teachers to inspire, educate, and engage with a certain number and type of students; a home enables affordable and healthy lives of its occupants, etc. The work of designers, builders, and operators accomplishes this performance and enables this value through the efficient allocation of materials and technical, financial, and human resources. This is a complex endeavor because of the difficulty in predicting many aspects that must be considered when making decisions about a facility. These decisions affect the duration and cost of the design and construction phase or the CO_2 footprint during operations, or the expected durability of the facility. In summary, a high-performance facility optimizes its performance across all the cost and income aspects shown in Figure 6. As mentioned, this is challenging to accomplish given the unique nature of each facility in its economic, environmental, and social context.

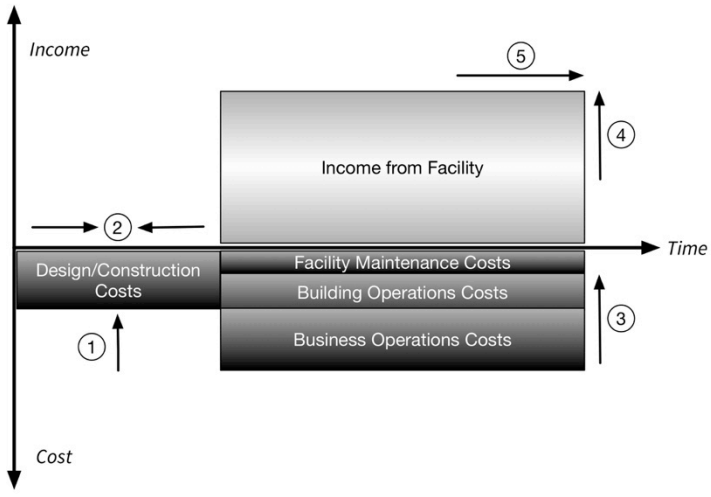

FIGURE 6. COST AND INCOME OF FACILITIES. ILLUSTRATION PROVIDED BY MARTIN A. FISCHER, STANFORD UNIVERSITY.

Today's project delivery process often attempts to optimize the design and construction cost and duration (optimization goals 1 and 2 in Figure 6). Minimizing design and construction duration benefits the project delivery team and the client because the project delivery team can add value to another project sooner and the client can obtain income from the facility as early as

possible (supporting optimization goal 4). The total income that can be generated from a facility does not only depend on its opening date, of course, but also on the income that the facility enables (optimization goal 4, the positive segment of the y-axis in Figure 6), and the duration during which the income can be generated (optimization goal 5, the duration of the use phase shown on the x-axis).

Integratred Systems

To effectively integrate systems a team must first identify the user values and tie them explicitly to the features that are being considered from a systems perspective for the building. The integrated team of owner, designers, and subcontractors should then build models to predict the behavior of the building relevant to characteristics valuable to the sponsor and stakeholders. These might include environmental impacts, operational parameters like energy consumption and ease of maintenance, usability considerations such as flexibility of the building's layout to changes in the users' business, constructability concerns or other factors.

For example, the DPR Construction Phoenix Regional Headquarters team modeled performance for its office remodel project and used CFD (computational fluid dynamics) simulations to predict the temperature distribution inside the building under various use criteria and at various times during the day and the year. This helped them design a passive cooling system that utilizes four direct- evaporative shower towers, 14 high-volume, low-velocity Big Ass Fans® hung throughout the ceiling, an 87-foot long by 13-foot high solar chimney, 82 Solatube® lighting units, louvers attached on the exterior walls and a Building Management System / BMS that controls these systems so that they respond together to maintain comfort inside the building given the environmental conditions outside. These elements were chosen to complement each other.

Figure 7 shows a cross-section of the DPR Phoenix office systems: the parking canopy system covered with photovoltaic panels, tubular daylighting devices for natural lighting, passive cooling tower, and solar chimney for heat exhaust. This conceptual model was developed to demonstrate how the various systems work together.

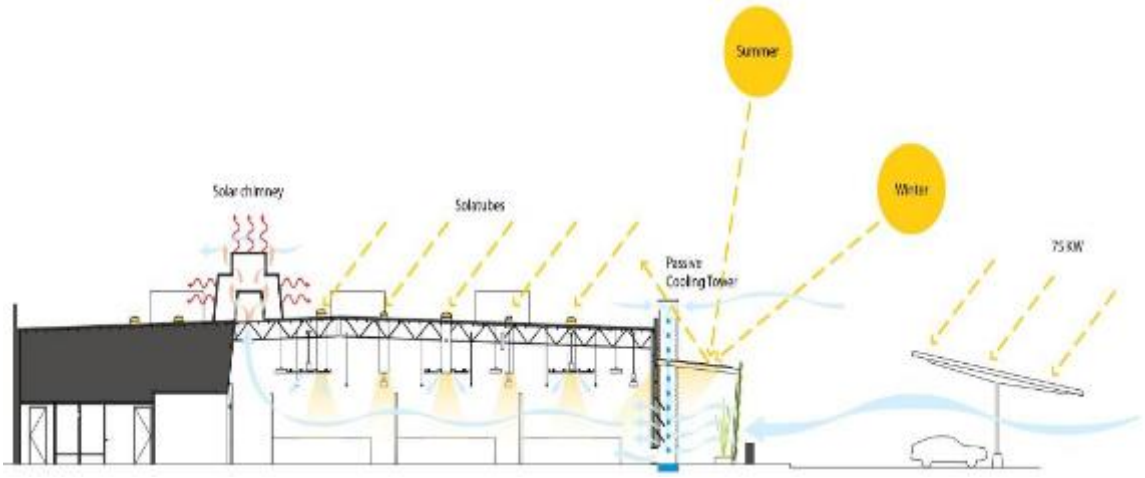

FIGURE 7. SMITHGROUPJJR; COURTESY OF DPR. SMITHGROUPJJR; COURTESY OF DPR CONSTRUCTION.

The plan view of the DPR Phoenix office building in Figure 8 illustrates the bioclimatic architectural strategy. The design takes into account the desert climate and environmental conditions, such as no prevailing wind, to help achieve optimal thermal comfort inside. It avoids complete dependence on mechanical systems, which are almost universal in the Southwest. These operate only as support when outside air is too hot to use.

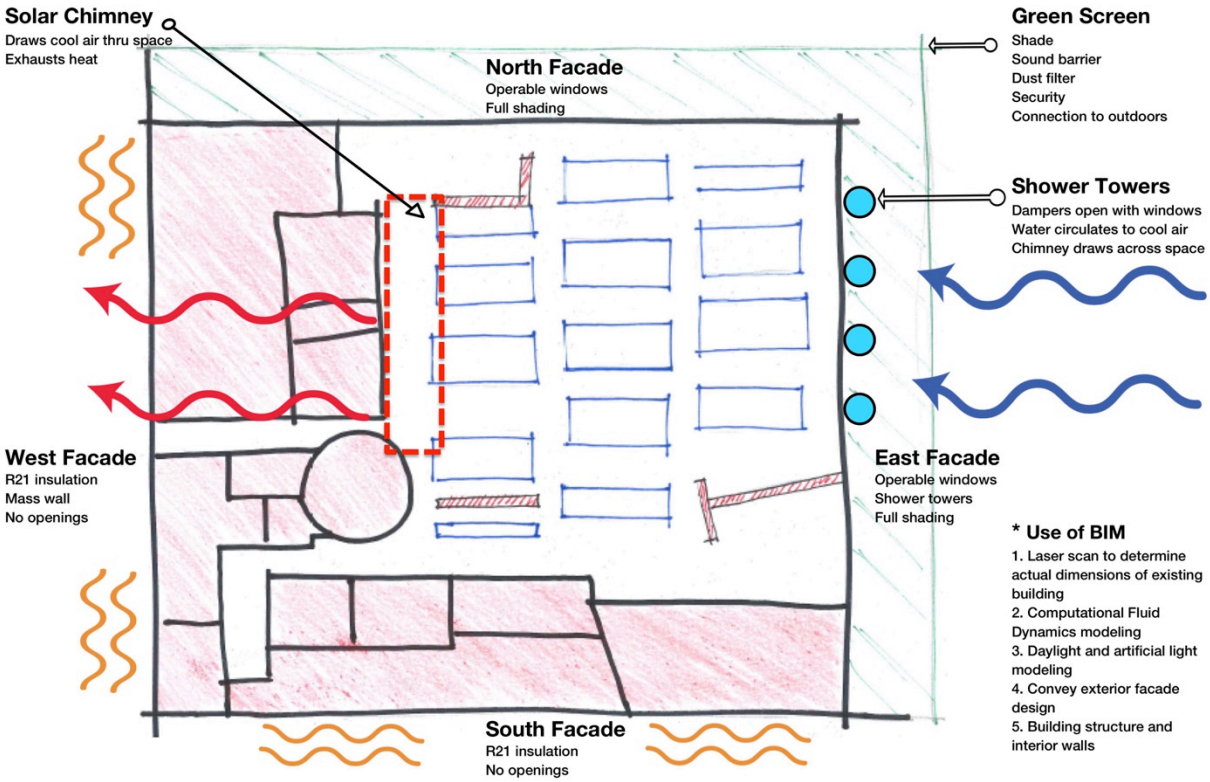

FIGURE 8. PLAN VIEW OF INTERRELATED SYSTEMS.DNV GL ENERGY SERVICES USA, INC.; COURTESY OF DPR CONSTRUCTION.

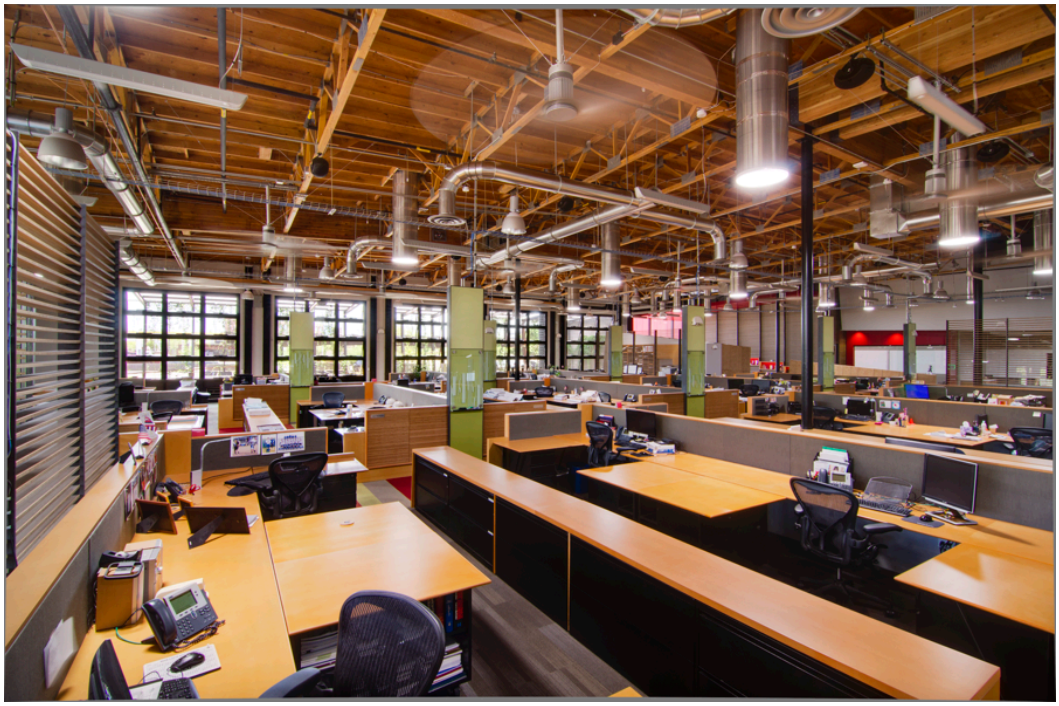

FIGURE 9. INTERIOR OF THE DPR PHOENIX OFFICE.

Integrating Process Knowledge

The output of the design phase must be the design of a facility that is valuable for its users, can be built, and can be operated. It follows that there are five main process integration needs, listed below and shown in Figure 10.

1. User value is translated into design solutions

2. Design informs and enriches user value and is checked against user value to ensure that user value does not get compromised as the design progresses

3. Builder's knowledge informs and shapes design

4. Operator's knowledge informs and shapes design

5. Sustainability concerns and knowledge informs and shapes design

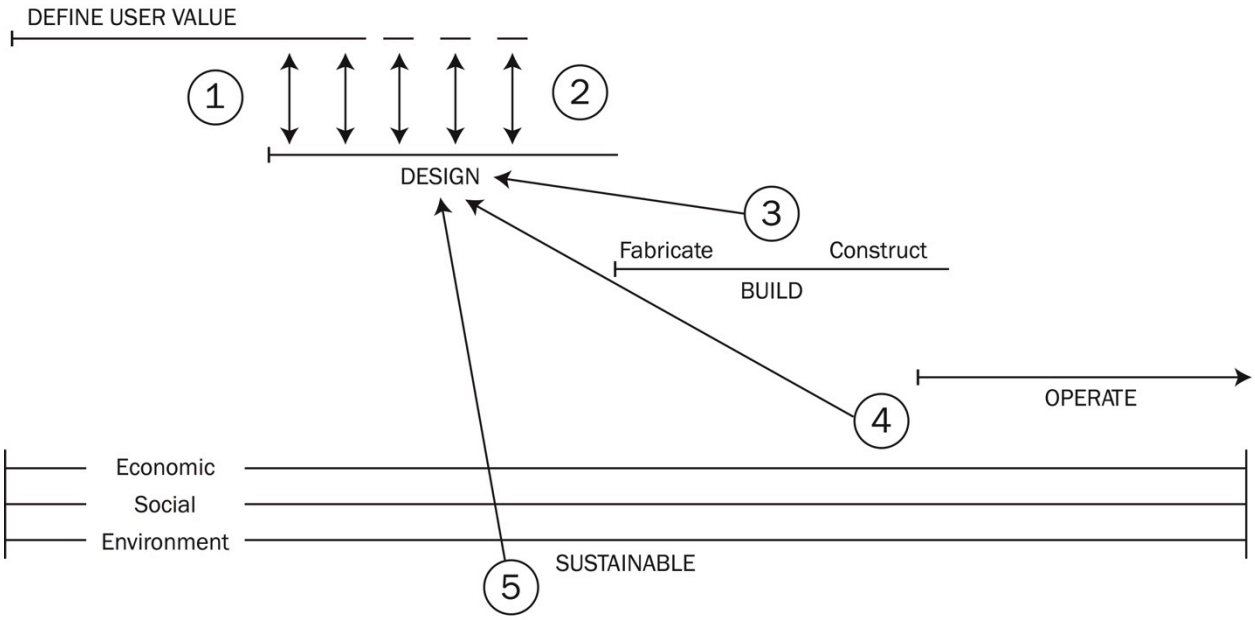

FIGURE 10. PROCESS KNOWLEDGE INTEGRATION.

Figure 11 shows a design review session. The designers and trade contractor modelers and managers were going through the coordinated BIM at the site office along with by other disciplines to understand the progress of design. This meeting was an all hands on deck meeting that occurred every other week during the design phase and was how the team integrated process knowledge.

FIGURE 11. COLLABORATIVE DESIGN REVIEW USING BIM. COURTESY OF SUTTER HEALTH; COURTESY OF GHAFARI ASSOCIATES, LLC.

Integrating the Project Organization

The integrated project organization aligns people to the project in four ways. It first connects people's actions, information and decisions. Individuals are not left to do this on their own in a hit-and-miss fashion. Second, the integrated project organization is literally built through and on people's use of language to make and keep commitments to do what they believe needs to be done as contributors. Third, the integrated project organization promotes individual and collective learning so that the organization's IQ is greater than any single individuals. Fourth, integrated project organization connects the work that people do through its structure to the unique combination of things that the end-customer, the client, has defined as value. Figure 12 shows Sutter Health's "Five Big Ideas that Are Reshaping the Design and Delivery of Capital Projects," which have guided their project teams. Taken together, they are building blocks people can use to integrate their project organizations.

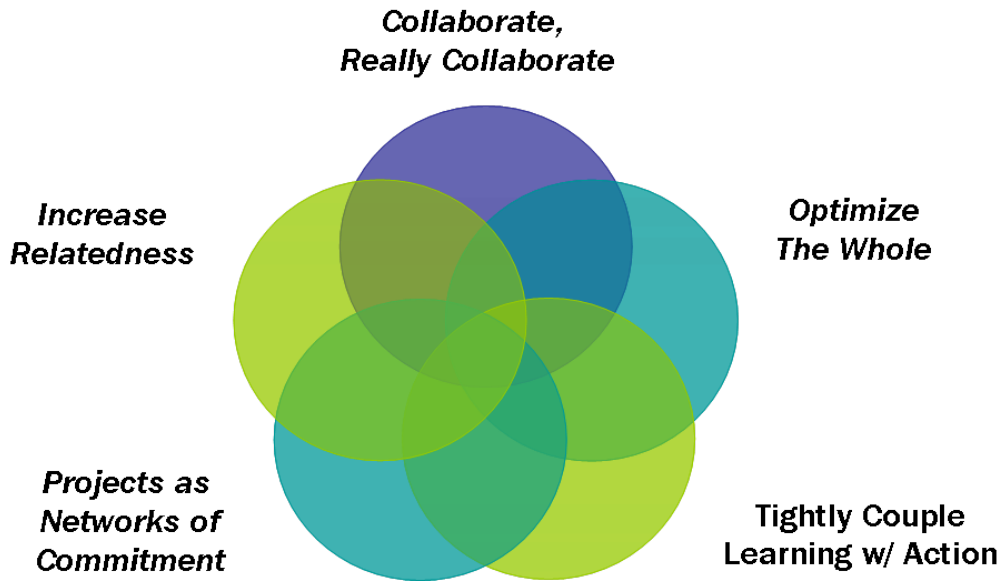

FIGURE 12. FIVE BIG IDEAS THAT ARE RESHAPING THE DELIVERY OF CAPITAL PROJECTS. COURTESY OF SUTTER HEALTH.

Lean thinking, management, leadership, and problem solving is the foundation for the integrated project organization. The sign, shown in Figure 13, posted on the fence of the Penn State University Agricultural Engineering Renewal project describes Lean principles and expectations.

FIGURE 13. LEAN FOUNDATION FOR THE INTEGRATED PROJECT ORGANIZATION. COURTESY OF DPR CONSTRUCTION.

Integrating Project Information

Decisions in a complex design and construction project are made constantly. As the project progresses and conditions (such as the design and schedule) change, the owner and the project team must respond swiftly. And, the decisions need to be well informed. Team leadership must have ready access to the latest relevant information including cost, scope, schedule, and quality. If the information is scattered throughout the project, in different formats, and located on different systems, project leadership is flying blind.

Integration requires exchanging information among disciplines. Without Integrated Information, critical information can become silo-ed within a discipline and not understandable to others. Integrated Information allows information to freely flow among disciplines creating the possibility of integrating processes and organizations. Figure 14 shows many, though not all, systems required for the Sutter Health Eden Medical Center Hospital. The Building Information Model integrates and makes available integrated information when it is taken to its lowest level – 5.

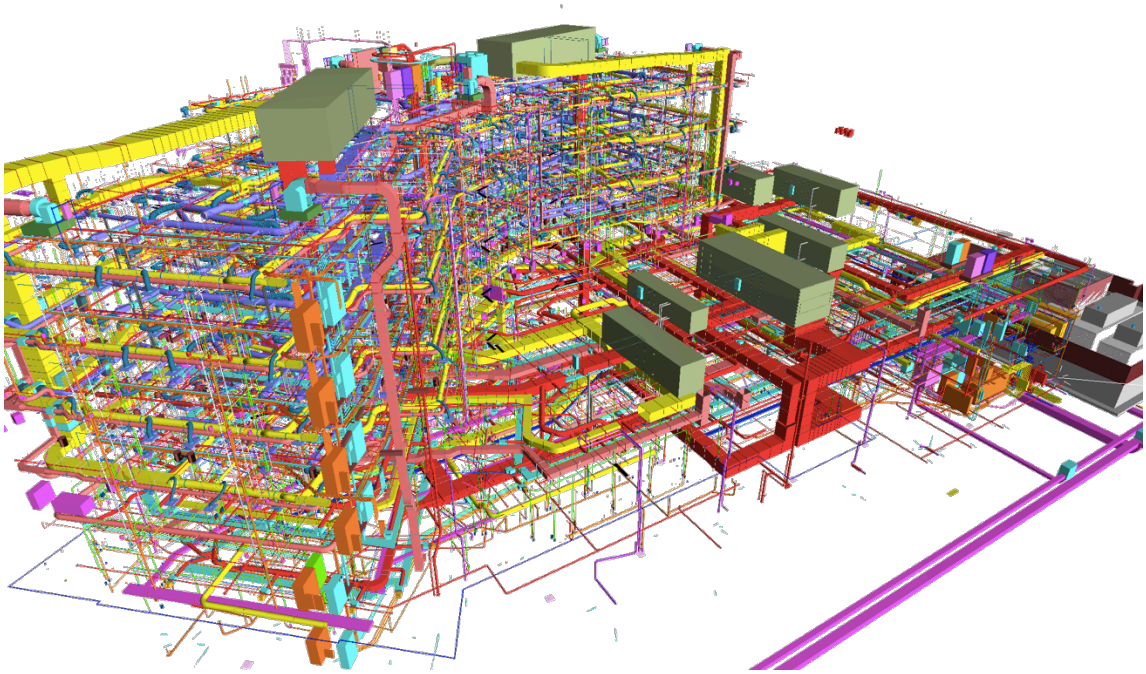

FIGURE 14. INTEGRATING SCOPE, QUALITY, COST AND SCHEDULE INFORMATION USING BIM. COURTESY OF SUTTER HEALTH; COURTESY OF GHAFARI ASSOCIATES, LLC.

Integrated Information coordinates information from all disciplines to provide an accurate representation of project reality. It allows project leaders to understand the current conditions and to allocate resources at their disposal in order to achieve specific project outcomes. It provides the tools for anticipating the consequences of their decisions.

Integrated Information also provides all project participants with the necessary information to perform their responsibilities and learning from studying outcomes in order to continuously improve work processes. Figure 15 shows what stakeholders and delivery team members can see and learn at each level of BIM.

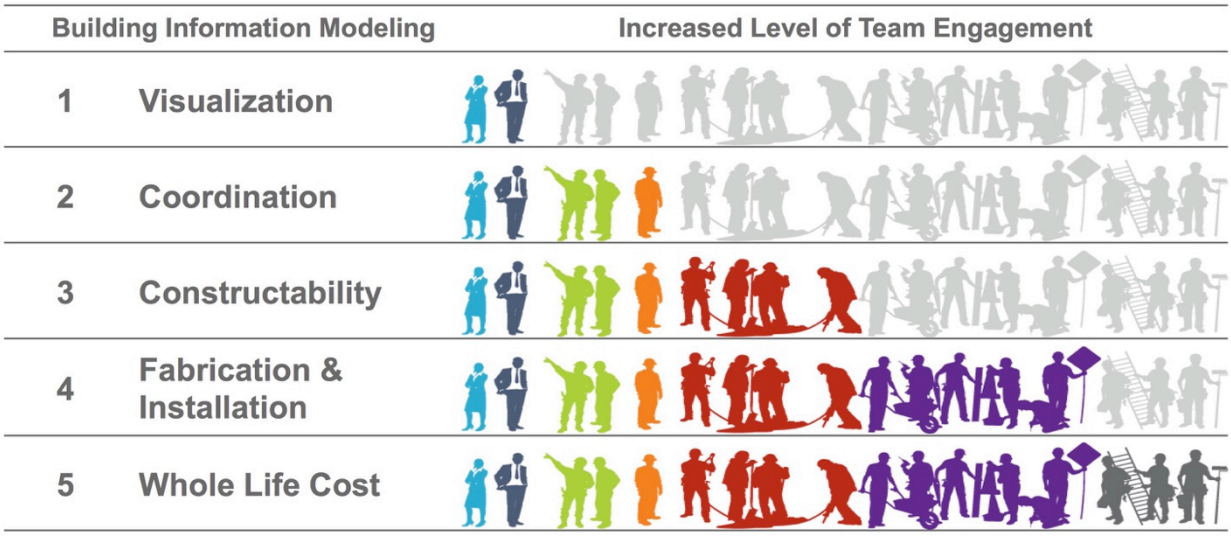

FIGURE 15. FIVE LEVELS OF BIM. COURTESY OF DPR CONSTRUCTION.

Using Metrics to Manage Integrated Team Performance

A team can and must decide how to shape and integrate its work processes, how to collaborate, and how to leverage technology. These decisions determine the allocation of resources – most importantly what the team pays attention to – and ultimately shape the selected design solution and its performance. Hence, the effectiveness of these decisions and the efficiency with which they are reached must be measured. Through measurement, a team can gain control over the objectives of a project and how to achieve them.

Measurement and control are directly related. Control is a verb. To control is to direct the project to desired outcomes. Control is forward thinking, focused on achieving what should be. Control should not be confused with project controls. Project controls are the measurement and analytical tools we use to determine state; i.e., what was and what is. We use project controls (measurement and analysis) to allow us to apply the correct control (direction) to manage the project. The challenge is to define metrics that relate to the project's goals and that provide information to project managers that enables them to assert control over the factors that affect project outcome

Figure 15 shows "Visual Control" in action, inspired by Toyota. The charts depict the progress being made each week to reduce cost, innovative solutions, wait-time for answers, and tasks completed as planned / PPC.. Each cluster team reported every other week staggered so that half had new information each week. The budget trend (1) and progress toward reaching the Target Cost (2) charts were updated each week for leadership meetings and prominently displayed so that every team member and visitor could see them. A big contributor to finding savings were Project Modifications and Innovations / PMI© proposals (3) from team members. The percent of material submittals approved without need for re-submittal (4), and percent of Requests for Information / RFIs answered without need for resubmittal (5), both of which are quality metrics, was also updated and charted weekly. The number of tasks planned and completed as planned (Plan Percent Complete) and the trend compared to the 80% goal (6) were also reported visually each week. The hundreds of people working on the project in the co-location space could see the progress they and other sub-teams were making towards designing and constructing the Mission Bay Medical Center within its budget.

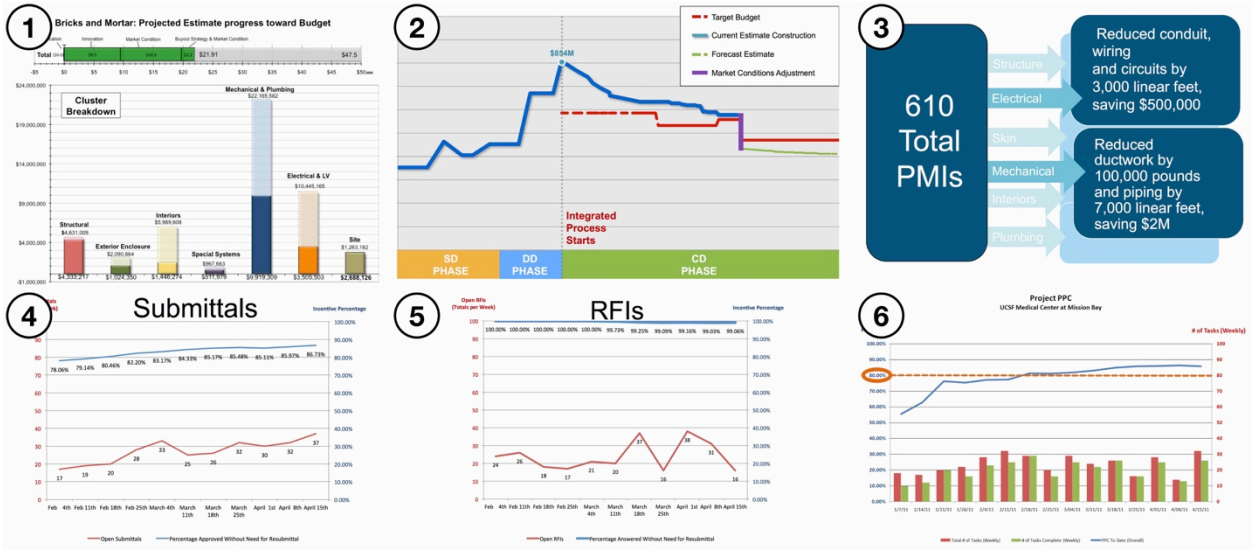

FIGURE 15: UCSF MISSION BAY HOSPITALS WEEKLY REPORTS FOR LEADERSHIP MEETINGS AND POSTING ON THE WALL FOR "VISUAL CONTROL." LICENSED BY THE REGENTS OF THE UNIVERSITY OF CALIFORNIA ON BEHALF OF ITS UCSF MEDICAL CENTER.

The UCSF Mission Bay team took on three major tasks concurrently. The first was completing development and documentation of design. The second was Value Engineering to significantly reduce construction costs while preserving value for the University, doctors, staff, patients, and their families. The third was to build the project virtually so that the work crews could install systems right the first time as productively as possible. The BIM team tracked clash resolution for the 935,000 gross square feet they modeled and coordinated. They were entirely guided by metrics and produced impressive results; Figure 16 shows the constraints removed through modeling and coordination at completion of the Construction Documents phase, when the entire design was submitted for approval by OSHPD, the California State hospital-permitting agency.

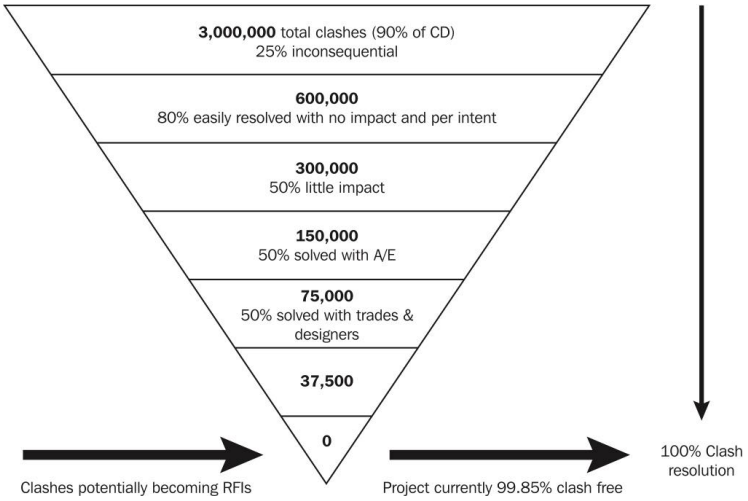

FIGURE 16. CONSTRAINTS REMOVED THROUGH MODELING AND COORDINATION. LICENSED BY THE REGENTS OF THE UNIVERSITY OF CALIFORNIA ON BEHALF OF ITS UCSF MEDICAL CENTER.

Visualizing and Simulating Performance

Visualization represents a product in a form that is meaningful to a diverse group of stakeholders and project team members, as shown in Figure 17. Visualization creates understanding of what the product looks like and how it will function. For example, a rendered 3-D model of a building represents how it will look, and can be used to communicate and develop a common understanding about the building's features.

FIGURE 17. STAKEHOLDERS SEEING THEIR SPACE IN 3-DIMENSION IN THE PENN STATE ARCHITECTURAL ENGINEERING CENTER CAVE. COURTESY OF DPR CONSTRUCTION.

Simulation is the prediction of a product's behavior based on analyzing an abstract model of the product. Because of the effort involved in a simulation and the advantage of considering many scenarios, computers are used to perform the calculations. For example, an energy model of a building that predicts energy use under changing occupancies, seasons etc. is a simulation model that can be used to predict actual energy use. Figure 18 shows one of the Computational Fluid Dynamics (CFD) simulations of the DPR Phoenix Net Zero Energy Building.

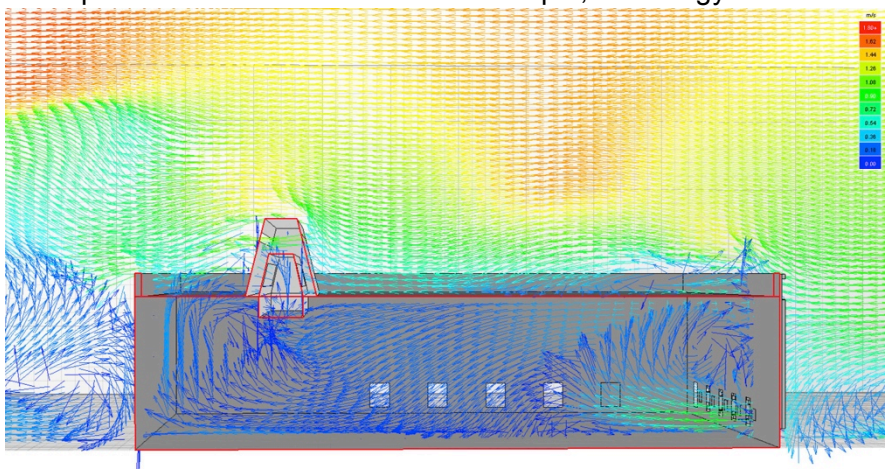

FIGURE 18. COMPUTATIONAL FLUID DYNAMICS SIMULATION OF THE DPR PHOENIX NET ZERO ENERGY BUILDING. DNV GL ENERGY SERVICES USA, IN.; COURTESY OF DPR CONSTRUCTION.

Collaborating to Improve Building & Team Performance

Collaboration is a community of people working together to achieve a common goal. In a project, the community is mostly defined by the immediate participants: designers, contractors,

trades, vendors and the owner. But in a larger sense, the community may also include end users, facility managers and regulators. In its broadest sense, the community is anyone that has a material affect on project outcome or who derives value from the project. Projects, especially complex projects, advance more smoothly when collaboration includes stakeholders and regulators, as well as the project participants. Figures 19 shows the Sutter Health Eden Medical Center Hospital team creating a better work plan. Designers and builders frequently gathered around a large digital display to analyze design details for constructability for that same project, shown in Figure 20.

FIGURE 19. COLLABORATING TO IMPROVE A WORK PROCESS. COURTESY OF SUTTER HEALTH; COURTESY OF GHAFARI ASSOCIATES, LLC.

FIGURE 20. COLLABORATING TO IMPROVE CONSTRUCTABILITY OF DESIGN. COURTESY OF SUTTER HEALTH; COURTESY OF GHAFARI ASSOCIATES, LLC.

Co-locating to Improve Design Quality & Problem Solving

Co-location is one of the most potent tools of the integrated project. Like aspirin, it is incredibly useful for a large variety of ailments, solving many difficult problems. Co-location:

1. Radically reduces latency (time to make decision);
2. Improves accuracy of communication through direct discussion and feedback;
3. Increases creativity through collision of different perspectives and ideas;
4. Provides designers with a fuller understanding of design consequences and alternatives;
5. Supports a common understanding of values, goals and project status;
6. Improves project management by making work visible;
7. Strengthens relationships among team members;
8. Supports decision making approaches like ICE and swarming;
9. Improves virtual communication that follows co-located work; and
10. Provides a location for visual management controls.

Figure 21 shows team members interacting in the UCSF Mission Bay Hospitals project Integrated Center for Design and Construction (ICDC)©.

FIGURE 21. THE UCSF MISSION BAY HOSPITALS PROJECT CO-LOCATED TEAM MEMBERS AT WORK. COURTESY OF HOWARD ASHCRAFT.

Managing Production as an Integrated Team

Value is created for owners / clients when their building is constructed or transformed. The planning to make that happen is necessary non-value adding from the Lean perspective. Figure 22 shows the elements of integrated production management and their relationships starting from the creation of value (1). The arrows show the flow of information from strategic planning (5), the most distant from value creation, and prerequisite for all other planning. Establishing project milestones is above the line to distinguish this work from production management. Steps 1, 2, 3 and 4 are the methods, processes and practices for that, all of which are essential for delivering valuable, high performing buildings – in fact, as opposed to intent.

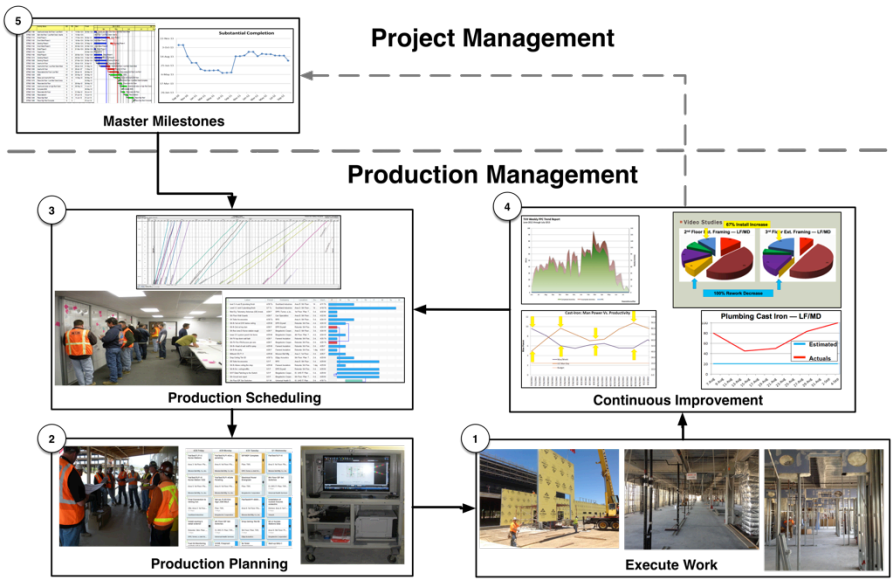

FIGURE 22. THE CONTINUOUS MANAGEMENT AND IMPROVEMT CYCLE OF PRODUCTION PLANNING.

Managing production requires a continuous improvement cycle. If we want flawless execution, we must plan production very well. If we want to plan production effectively, we must do a very good job of scheduling production. If we want to schedule production, we need to know how well

we are doing so we can continually improve performance. If we want to schedule production, we must also create a sound plan for what should happen within the Master Schedule. If we want meaningful milestones to steer the project and plans to execute work, we must incorporate what we've learned from studying what we've done in real-life. This is Lean production in construction.

Making value flow at the pull of the end and intermediate customers is a cornerstone of Lean. Lean thinkers and managers focus on optimizing for throughput / time before resource utilization, which is not the current practice in design and construction, where the goal is cost control.

Pull planning is the way to plan the hand-offs between crews so that suppliers produce and customers get what they needed. Participants, whether in design or construction, realize that pulling is the alternative to command and control by top managers. In construction, trade foremen plan each large phase of work and also for particular production targets by pulling back from one or more milestones in the Master Schedule. These planning sessions typically last about 3 hours in the beginning and progressively less as the team becomes better at the process. Figure 23 shows a "I Get | I Give sticky note and a foremen pull planning session. Participants learn to describe what their teams / crews need in the top half, I Get space, and what their crews will deliver in the bottom, I Give space, on special sticky notes and put them in the right order on a whiteboard.

FIGURE 23. I GET | I GIVE STICKY NOTE AND TRADE FOREMEN PULL PLANNING. COURTESY OF DPR CONSTRUCTION.

Collaboration is the basis of integration. True collaboration, as opposed to cooperation, requires that people trust each other to do what they say, and help each other when they need it. One of the reasons to invest in integrating information is for everyone to know the current reality so they can improve their own and others' effectiveness. Cloud-based software can and should make information transparent. Figure 24 shows a weekly production plan created in BIM 360 Plan by trade foremen, taking into account actual conditions and constraints such as design issues and material deliveries. The screenshot also shows how foremen report progress for every task they've planned and committed to complete during the current work period.

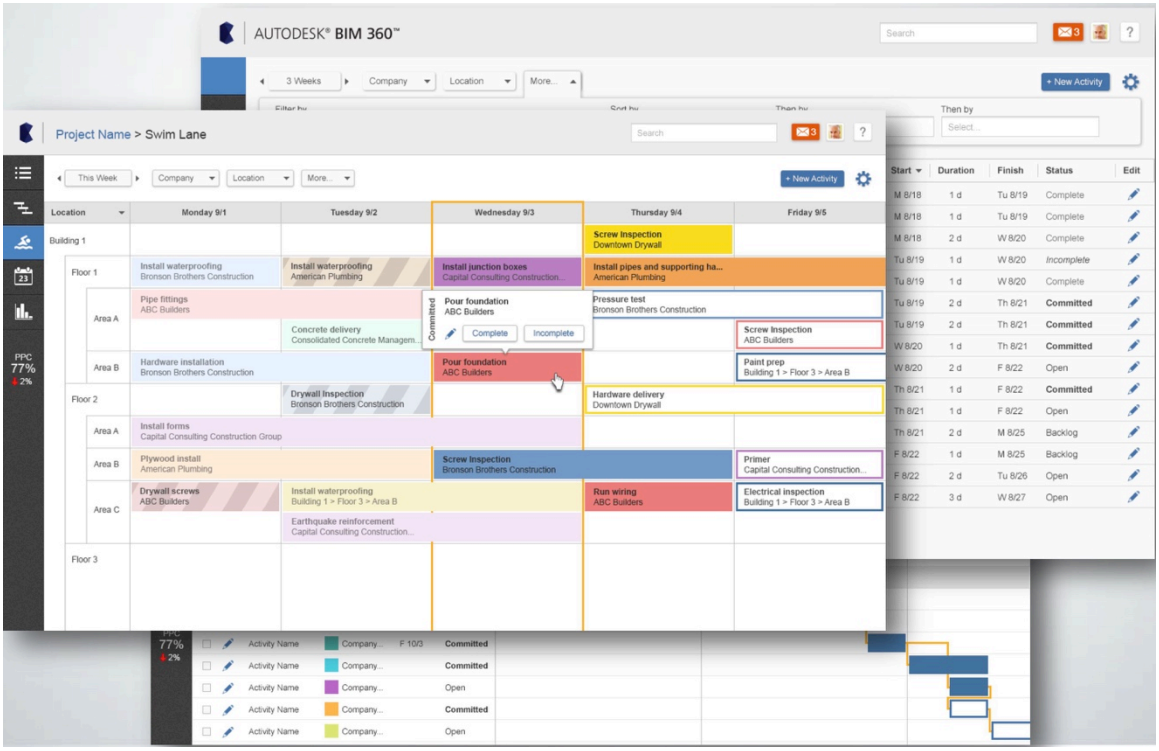

FIGURE 24. BIM 360 PLAN MAKES THE PLAN AND PROGRESS TRANSPARENT AND AVAILABLE TO ALL.

A recurring problem on construction projects is that not everyone who needs the latest information has easy access to that information. Project teams can only be successful if each and every one of the people working on the project has access to accurate, current and complete information. In Figure 25 a field foreman uses an iPad to look at the detailed model of the wall framing and utilities that would be installed in the wall after they had completed their work. This gives field personnel integrated information and the ability to visualize where it is needed, in production.

FIGURE 24. FIELD FOREMAN LOOKING AT BIM FOR FRAMING AND IN-WALL UTILITIES DETAILS. LICENSED BY THE REGENTS OF THE UNIVERSITY OF CALIFORNIA ON BEHALF OF ITS UCSF MEDICAL CENTER; COURTESY OF DPR CONSTRUCTION; COURTESY OF MIRROR MIRROR DIGITAL MEDIA,INC.

The production schedule must reflect real capabilities under current conditions. Those responsible for it must create a rapid feedback loop to incorporate what they are learning from on-going work. They must know whether the crews are meeting production, safety, and quality objectives. This is the role of metrics for completing work as planned. Productivity, injuries, inspections passed, and rework must be measured. Work must be standardized to remove variations that mask root causes. The team managing production must look at the results to see problems that they wouldn't see otherwise, especially in the sequencing and pace of production. After each change in work methods, the team must accurately measure to determine whether the adjustment was effective, and armed with the new information, repeat the process.

Jason Herrera, Manager of DPR Construction Southern California's Drywall Group has extended the use of productivity dashboards in combination with tracking Plan Percent Complete and reasons for failing to complete work within the Last Planner® System. Figure 25 shows the monthy report his management team produces for their large projects.

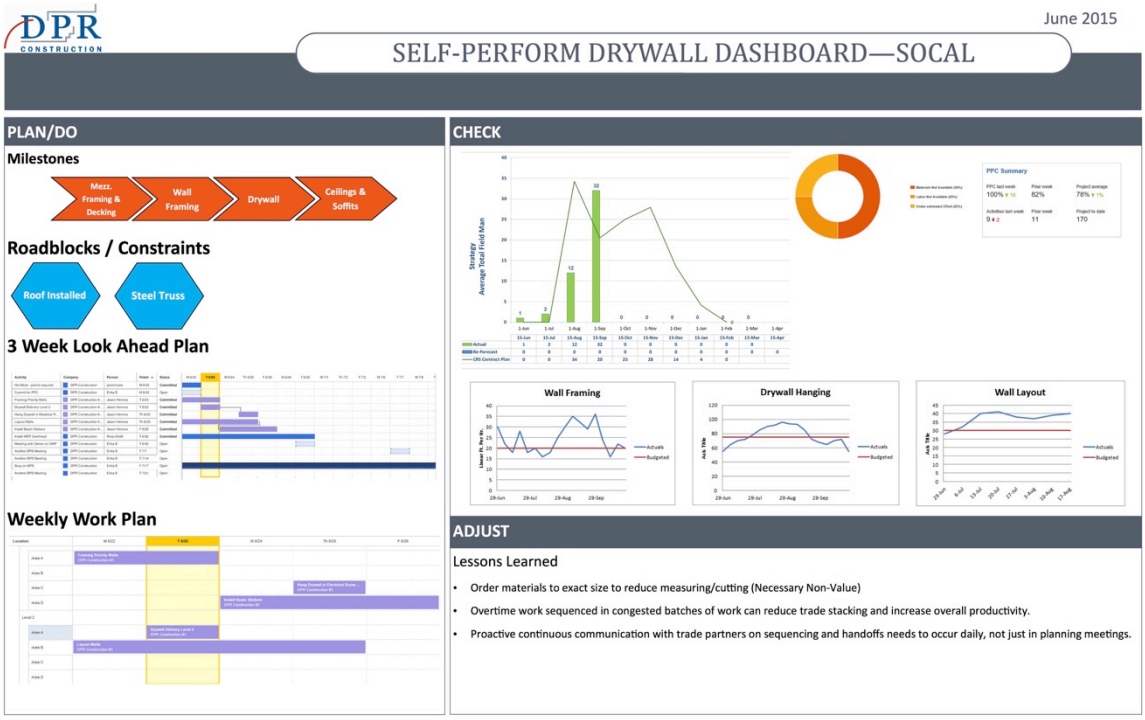

FIGURE 25. DPR CONSTRUCTION SOUTHERN CALIFORNIA SELF-PERFORM DRYWALL GROUP PRODUCTION PLANNING AND PRODUCTION DASHBOARD. COURTESY DPR CONSTRUCTION.

The Big Picture of Integrating Project Delivery

Figure 26 shows what stakeholder and participants can expect to see on a project where the team is truly integrating and sharing knowledge and information in design and construction.

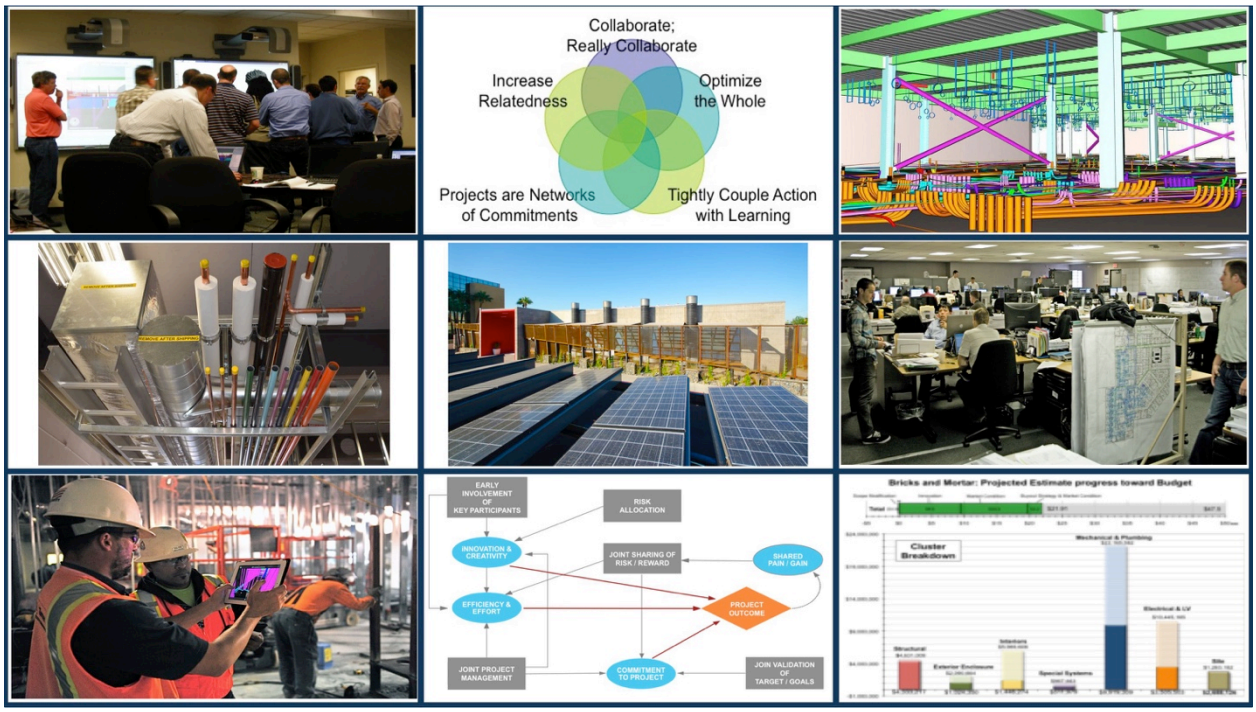

FIGURE 26. WHAT YOU CAN EXPECT TO SEE WHERE A TEAM IS INTEGRATING PROJECT DELIVERY.