Proceedings of the 15th Annual Conference of the International Group for Lean Construction
Lansing, Michigan, July 18-20, 2007

PRIORITY CONVERSATIONS: A CASE STUDY ON PRIORITY WALLS

Samir O. Mikati[1], Timothy G. Roller[2], Iris D. Tommelein[3], and Atul Khanzode[4]

ABSTRACT

This paper presents and analyzes work structuring and collaboration efforts of the general contractor and specialty contractors working together as a team to implement lean practices during construction of a medical facility. We describe the team's focus specifically on 'priority walls' as a driver for coordinating work among contractors. We then elaborate on the tools the team used to support their language ("priority conversations") and action, as well as on the successes and failures of their approach. Success of this effort stems from the team's willingness to experiment, collaborate, and learn; use of an owner-provided incentive sharing plan; and other lean practices including use of the 'big room' ('oba' or 'oobeya' in Japanese), development of a Building Information Model (BIM) that allowed for integration and coordination of trade-specific design details, promotion of reliable planning, as well as use of standardization combined with offsite fabrication and assembly. The paper illustrates how this combination of lean practices changed the nature of the conversation specialists have in the course of development of a project and yielded value to all project participants as well as to the project as a whole.

KEY WORDS

Lean construction, work structuring, reliable planning, contract incentive, language action perspective (LAP), coordination, collaboration, oba, oobeya, big room, Building Information Model (BIM), medical facility, Sutter Health, Camino Medical Center.

INTRODUCTION

Building systems (e.g., mechanical, electrical, plumbing (MEP) systems, fire protection, and drywall) account for a significant portion of the cost to construct high-tech facilities such as hospitals and laboratories. MEP systems on technically challenging projects may account for as much as 50% of the total project cost (Tao and Janis 2001). A challenge to design- and construction specialists is to fit ever-more interconnected and dense systems into smaller spaces, and do so under increasingly stringent time constraints. Coordination therefore is of utmost importance (Riley and Sanvido 1995, 1997, Tommelein and Ballard 1997, Holzemer et al. 2000, Korman et al. 2003, Tatum and Korman 2005, Korman and Tatum 2006). As the complexity of facilities increases, better practices for collaboration must be developed in order to effectively address their delivery challenges.

This paper presents a case study pertaining to the design and construction of the Camino Medical Center. On this project, several lean practices were used in combination, namely

[1] Undergraduate Student, Civil and Environmental Engineering Department, University of California, Berkeley, CA, smikati@berkeley.edu
[2] Undergraduate Student, Civil and Environmental Engineering Department, University of California, Berkeley, CA, timroller@gmail.com
[3] Professor, Civil and Environmental Engineering Department, and Director, Project Production Systems Laboratory, http://p2sl.berkeley.edu/, 215-A McLaughlin Hall, University of California, Berkeley, CA 94720-1712, Phone +1 (510) 643-8678, FAX +1 (510) 643-8919, tommelein@ce.berkeley.edu
[4] Business Analyst, DPR Construction, Inc., 1450 Veterans Blvd., Redwood City, CA 94063, and Graduate Student, Civil and Envir. Engineering Department, Stanford University, Stanford CA, atulk@dprinc.com

(1) willingness of project participants to experiment and learn, (2) recognition that collaboration among project participants is crucial to project success, (3) implementation of an owner-provided incentive sharing plan, (4) support for reliable planning, (5) use of the 'big room' ('oba' in Japanese), (6) development of a Building Information Model (BIM) that allowed for integration and coordination of trade-specific design details, and (7) extensive use of offsite fabrication and assembly. We will describe these practices in the context of the project studied and then elaborate on how they contributed to the project's success.

CASE STUDY BACKGROUND

Sutter Health is a major healthcare provider in northern California. To date, it appears to be the largest owner organization in the United States to embrace lean project delivery for all of its projects. By choosing to 'go lean,' Sutter wants to be the owner of choice at this time when hospital construction is booming.

Sutter is spurring industry participants to engage in its lean journey by promoting its lean thinking through 'Five Big Ideas' (Macomber 2004, Lichtig 2005, 2006, Hurley 2006):

1. Collaborate, Really Collaborate
2. Manage as a Network of Commitments
3. Increase the Relatedness of the Project Participants
4. Tightly Couple Learning with Action
5. Optimize the Project at the Whole

These ideas were pursued in the delivery of the Camino Medical Center, a project for the Camino Medical Group (CMG). CMG is a division of the not-for-profit Palo Alto Medical Foundation which is a Sutter affiliate (CMG 2004). The Camino project is located in Mountain View, California. Construction of this $100 million medical office building with surgery center and urgent care clinic is among the first in Sutter's portfolio of lean projects comprising $6 billion of investment over approximately 8 years.

Design of the Camino project began in October 2003 and construction in February 2004. The project is now completed and the facility is open for business. Table 1 lists the major project participants. Figure 1 renders the design of this 22,500 m^2 (250,000 ft^2) facility. The design is arranged using a 'quadrant layout,' consisting of two main buildings each with two sections, and an atrium in the middle. Each quadrant is labeled according to its geographic location (e.g., one quadrant is called the South-West (SW) quadrant).

RELATED WORK

A major task of contractors is to determine means and methods for construction, but means and methods are not the only factors that affect production performance. Work sequencing, not only within a trade but especially across trades, can have a major impact on production performance because of trade interdependence. For example, by installing wall studs and drywall, open floor space gets partitioned into room-size areas. This breaks up the flow of work that is preferred by contractors installing floor-wide systems, such as sprinklers and HVAC ductwork (Riley and Sanvido 1995). On some projects, general contractors use their drywall subcontractors to push the other trades ahead by threatening to break up their open floor space. On other projects, subcontractors are left to fend for themselves. When that is the case, the mechanical contractor may end up in the lead—with or without getting compensated for taking on the coordination role—but out of self-interest in seeing to it that their and other subcontractors' work on site gets coordinated. Some front-line subcontractors have experienced significant gain in teaming up and then implementing lean practices, to the point where they were willing to pay the general contractor for refraining from taking actions that would hamper their production team's performance (Neenan 1999).

Table 1: Participants in the Camino Project

Company	Role
Sutter Health	Owner / Client
KPFF	Structural Engineer
Hawley, Peterson, and Snyder (HPS) Architects	Architect
DPR Construction, Inc.	General Contractor, self-performing drywall work
Cupertino Electric	Electrical Subcontractor
Southland Industries, Inc.	Mechanical Subcontractor
J.W. McClenahan	Plumbing Subcontractor
NorthStar Fire Protection	Fireproofing Subcontractor

Figure 1: Rendering of the Camino Project (Hurley 2006)

The need to manage interdependence and uncertainty in construction is well-known (e.g., Crichton 1966): both pose numerous technical and management challenges. For example, when activities are scheduled in a tightly-linked sequence, those downstream will get hampered by upstream variation (e.g., as illustrated in the Parade Game by Tommelein et al. 1999). Challenges escalate as product complexity and pressure for shorter durations increase. This paper elaborates on means to manage interdependence and reduce project uncertainty.

Interdependence can—in part—be managed through work structuring and coordination. 'Work structuring,' when used as a lean construction term, refers to managing transformations (i.e., 'Who should be doing what?,' 'How?,' and 'At what time in the course of delivery of a project?') while at the same time managing flow (e.g., 'What defines handoffs between project participants?,' 'When do handoffs occur?,' and 'Are handoffs immediate or buffered?') and generating value (Koskela 1992, 2000). Work structuring includes determining who is in the best position to do what, together with how and when each project participant is to apply their abilities and fulfill their commitments (Ballard 1999, Tsao et al. 2004, Tsao and Tommelein 2007). Contractors price their bids more favorably when they know that a skillful manager (e.g., a field superintendent) will coordinate all work on site (e.g., Birrell 1985, Tommelein and Ballard 1997).

Uncertainty can—in part—be alleviated by increasing plan reliability (e.g., Ballard), which includes creating transparency and predictability across the supply chain, hand-in-hand with production control (here, in the lean sense, production control is defined as the pro-active steering of work on the schedule as the project progresses).

Notwithstanding recognized needs, project participants and the industry at large are struggling to meet increasing demands for understanding that will help them better manage the situations they face. In this paper, we show how new processes are being developed and collaboration systems are emerging based on changes in language and action (e.g., Flores 1982, Howell et al. 2004) that enhance project management practices on complex projects.

PRIORITY WALLS

A 'priority wall' is a full-height wall (usually a fire-rated wall) where drywall cannot be put in-place if ductwork (or other specialty trade work) has already been installed (after Napier

2006). The alternative to full-height walls are walls that reach up only to the plenum space. Correspondingly, the drywall contractor must work on a priority wall, before other trades get to do their work, but may not be able to complete all drywall work at once; that is, steps in the installation process of a priority wall have reciprocal dependence. Specialty trade work other than mechanical ductwork installation tends to be smaller in size and therefore has less impact –if any impact at all—on priority wall decisions.

Figure 2 illustrates a priority wall. Metal wall studs (left-hand side) form the full-height wall partition. HVAC ductwork (center) is routed closely adjacent and parallel to the wall. Should that ductwork be put in place first, the drywall contractor would not be able to reach up behind it in order to install drywall. Thus, this section of wall with closely-adjacent ductwork gets designated as a priority wall. As shown, the drywall contractor has placed drywall from the ceiling down to the bottom level of the duct. Duct was then installed. The remainder of the wall is not yet sheeted in, so as to let other specialty contractors do their work and for inspection to take place, before the wall is closed up. Figure 3 summarizes the work sequence for constructing a priority wall.

Figure 2: Example Priority Wall on Camino Project (photo courtesy of DPR Construction, Inc. Redwood City, CA)

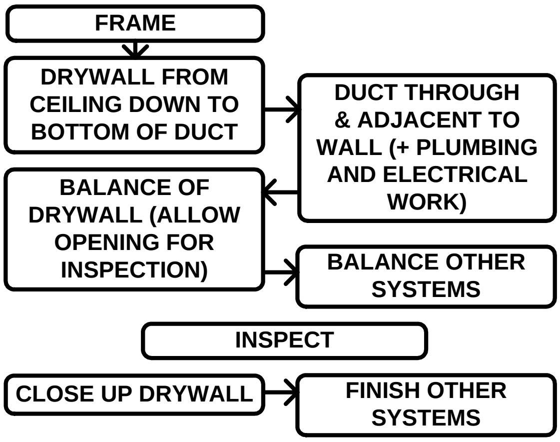

Figure 3: Flow Chart of Work Sequencing for Priority Walls

Not all priority-wall designations are so clear-cut as the example shown in Figure 2. The general contractor and the drywall-, mechanical-, and other specialty contractors are likely to have common understanding of what constitutes a priority wall (other terms may be used in practice) however, they may also disagree. For example, it is a matter of opinion whether or not 15 cm (6”) of horizontal clearance suffices to allow for ‘efficient’ access between a duct section and a wall while considering their height. The designation of priority-wall status must therefore get finalized in the course of conversation during coordination meetings. To refer to such conversations, Iris Tommelein coined the term ‘priority conversations.’

Each specialty contractor prepares for each such meeting by analyzing their work in the relevant part of the design (using blueprints or a 3D model) and highlighting which walls should be priority in their opinion. During the meeting, each person then suggests which walls should be priority and disagreements must be resolved. Depending on the circumstance, a priority wall can take 2 to 4 times longer to build than a regular wall (Napier 2006), so it is important to judiciously assess which walls should or should not get priority.

The question ‘Which wall should be classified as priority?’ boils down to ‘Which trade(s) is (are) going to a take a productivity hit?’ Priority walls typically impose the use of a work sequence that is less-than-optimal when viewed from the perspective of each individual trade. Specialty contractors other than the drywall contactor would like to minimize the number of priority-designated walls because their productivity will decrease if they must install their systems around drywall that, using another sequencing rationale, may not have been in the way. Even for the drywall contractor, having a wall classified as priority is not ideal because it means having to install drywall on walls in different locations and at different times than they normally would consider to be efficient.

When prioritizing work of one specialty over another, pains and gains tend to be imbalanced. Certain work may be structured to progress unrestrained in certain areas so as to yield the project greater benefit than other work would. For the prioritization system to benefit the project as a whole, loss of productivity of some trade(s) due to using the priority wall classification must be outweighed by gains realized by other trade(s). Even though the productivity of several specialty contractors may be adversely affected by priority wall sequencing in certain work areas, productivity of the project as a whole may still benefit when work is duly planned around priority walls, thanks to an increase in predictability of work flow and the elimination of costly rework.

Given the nature of the Camino project, about 60-70% of all walls within the surgery unit (which is extremely complex) were identified as priority walls, and about 15% of the walls in the remainder of the facility; the latter percentage is more typical of office buildings in general (Burrows 2006).

Using this focus on ‘priority walls’ as a driver for coordinating work among specialty contractors, we next elaborate on the tools the team used to support their language and action, as well as on the successes and failures of their approach.

WILLINGNESS OF PROJECT PARTICIPANTS TO EXPERIMENT

The uniqueness of the Camino project stems from several factors, not in the least the willingness of project participants to engage in experiments, set up to allow for learning in the course of delivering this project, and to carry lessons learned forward to other projects (e.g., Hurley 2006).

Unlike broker-contractors who do not self-perform any work, the GC on this project self-performed concrete as well as drywall installation work (self-performing drywall is a more exceptional practice for a GC). The GC can use this work to establish rhythm on the job, that is, set the pace or act as a throttle for other work. Willing to experiment, and motivated by an incentive sharing plan, as explained later, the GC allowed other trades to work ahead of drywall installation in judiciously-chosen locations even though this impacted their drywall productivity significantly.

COLLABORATION AMONG PROJECT PARTICIPANTS

Delivery teams on complex projects know that effective collaboration among all participants is crucial to overall project success. Collaboration on the Camino project was supported by a unique relational contract combined with process experimentation and refinement during execution. This contract included the beginnings and evolved to what is now known as the ‘integrated form of agreement’ (Lichtig 2006) that Sutter is using on more recent projects.

INCENTIVE SHARING PLAN

On the Camino project, the key specialty contractors held Guaranteed Maximum Price (GMP) contracts with the GC. A GMP contract is a two-way contract in which the owner may provide an incentive to the contractor for staying below the maximum price, e.g., by offering to share savings. Here, however, the owner working with the GC enhanced these GMP contracts with an incentive sharing plan (Figure 4), according to which specialty contractors with GMP contracts were to contribute to a project purse, the ‘Total Cost-of-work

Savings Pool.' Funds in this pool would be distributed three ways: 50% going back to the owner, 25% being divided among the contributors, and 25% being the first contribution to the 'Total Incentive Pool.' The second contribution to the 'Total Incentive Pool' is 50% of the unused design contingency and construction contingency during construction. The other 50% of the unused contingencies would go back to the owner. The 'Total Incentive Pool' would be divided between the architects and the general contractor, each of which was to award 40% of the sum thus received to their respective sub-consultants and subcontractors.

Through this incentive plan, the owner implemented the Big Idea 'Increase the Relatedness of the Project Participants' and wanted to encourage project participants to give-and-take for the benefit of the project overall, i.e., pursue the Big Ideas 'Collaborate, Really Collaborate' and 'Optimize the Project at the Whole.' For example, as a result of this agreement combined with priority conversations, the drywall contractor (= the GC) delayed some of their work and took a productivity hit, in order to allow MEP contractors to be more efficient.

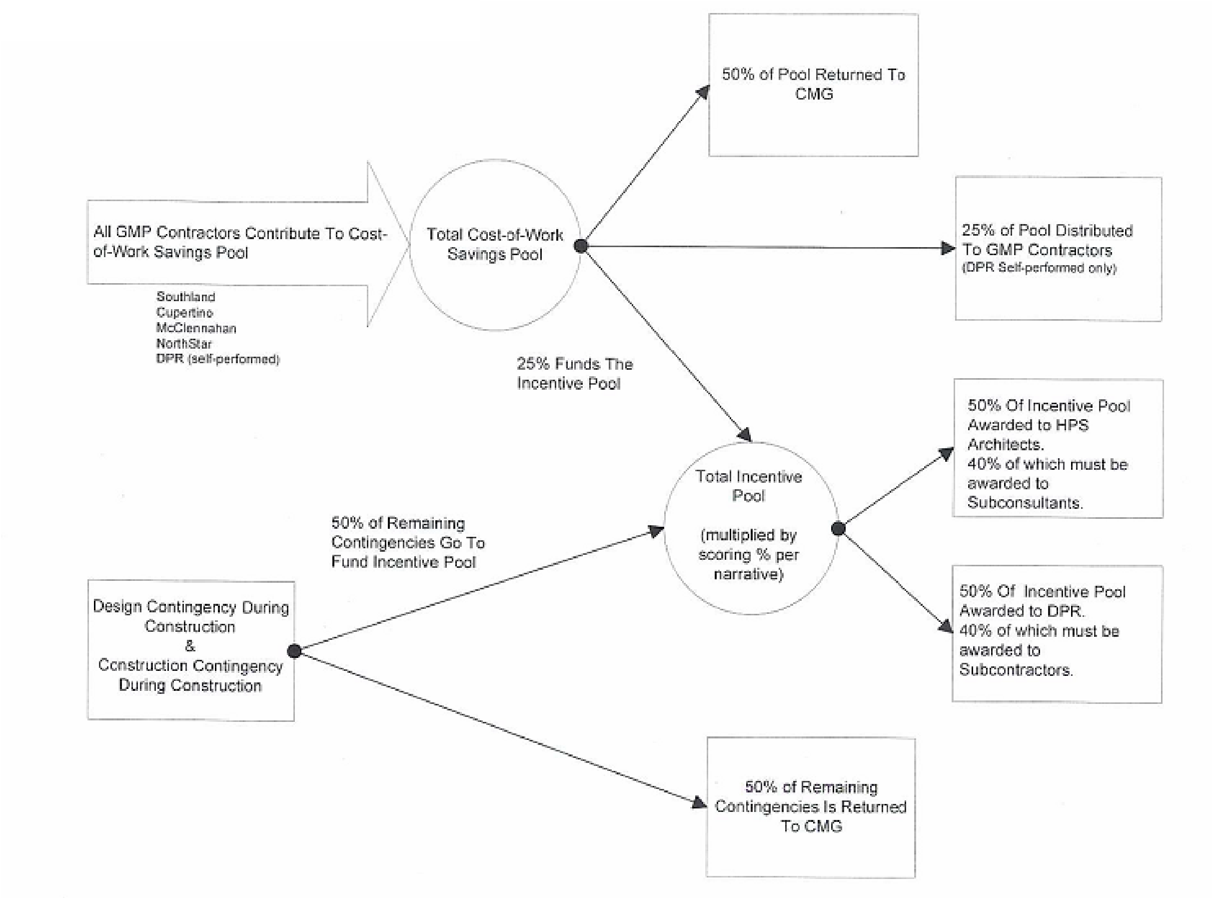

Figure 4: Camino Medical Group Incentive Plan (CMG Document, not dated)

'BIG ROOM' OR 'OBEYA'

Another contractual requirement was for all design detailing work by specialty contractors to be done on site, so detailers working for the MEP contractors were co-located in a double trailer. This trailer served as the 'obeya.' "Obeya in Japanese means simply 'big room.' At Toyota it has become a major project management tool, used especially in product development, to enhance effective and timely communication. Similar in concept to traditional 'war rooms,' an Obeya will contain highly visual charts and graphs depicting program timing, milestones and progress to date and countermeasures to existing timing or technical problems. Project leaders will have desks in the Obeya as will others at appropriate points in the program timing. The purpose is to ensure project success and shorten the plan-do-check-act cycle" (Lean 2007). "The visual tools used in the o(o)beya along with the structure and discipline required to use them effectively have enabled a few companies to dramatically shorten project cycle time and quality (Tanaka 2005).

On the Camino project, the Big Room served exactly that purpose; it served the Big Idea "Tightly couple learning with action." Specialty detailers could have priority conversations, coordinate their work, and readily work out solutions with other specialists because they were collocated. The conversation was further aided by their use of 3D CAD modeling (discussed later). Notwithstanding many benefits experienced in the Big Room, specialty detailers found it painful when it came to commuting to and from the site to conduct all of their work, especially because it was computing work that could easily be done elsewhere.

VIRTUAL PRODUCT MODEL USING BUILDING INFORMATION MODELING

Building Information Modeling (BIM) (e.g., Birx 2005) was an enabler for lean project delivery on this project as it allowed for integration and coordination of design as well as trade-specific design details. The project architect, Hawley Peterson and Snyder (HPS), was contractually responsible for creating the overall 3D model, whereas design specialists and subcontractors were responsible for modeling their respective building systems (Hurley 2006). In order to create a virtual model that incorporated all specialties, the design teams of all key companies met early on in the design process and established protocols (such as which software to use, how much detail to model, etc.) that allowed for an integrated, comprehensive model to be generated (Khanzode et al. 2005, Staub-French and Khanzode 2007). The tools used to create this model included conceptual design and rendering tools, AutoCAD, ETABS 3D Analysis for structural design, Autodesk Architectural Desktop (ADT) (Revit existed only in beta version at the time) for building information system integration, Pipe Designer 3D, Fab Pro, and Navisworks Jetstream to integrate specialist models into a comprehensive whole and to detect clashes.

Several benefits accrued from a virtual model being developed early and being used throughout the life of the project. With detailers all present in the Big Room, systems could be coordinated without much ado. Furthermore, specialty contractors—esp. those with a design-assist contractual agreement, such as the mechanical contractor—could design and detail their work while exploiting opportunities for standardization and offsite prefabrication. With early availability of relatively detailed design information, combined with the promise of reliable construction scheduling, and visualization allowing for detailed logistics planning (e.g., minimize handling on site by using carts on wheels) specialty contractors could plan to bring in even larger assemblies. During installation, this avoided collisions and field modifications, in turn resulting in a significant reduction in onsite labor hours (Hurley 2006).

Reports from various project participants consistently showed that the cost of generating their respective 3D model was small relative to the cost of construction. For example, DPR and its project team including designers and subcontractors estimates its costs of modeling beyond 2D to be about $415,000, or only 0.44% of the total construction cost. Although this paper does not aim to quantify all monetary gains accrued from the implementation of a 3D model, it is clear that a very small margin on this project would offset the $415,000 cost of implementing the 3D model.

RELIABLE PLANNING

The link between these innovative approaches, and a pillar of lean construction, is reliable planning. On the Camino project, 'trailer meetings' attended by specialty-contractor representatives and the GC were set up to coordinate work; they were led by a senior engineer working for the GC. Prior to the start of construction, these meetings were conducted to sync up detailing work completed by different specialists (using Navisworks Jetstream) to create an integrated 3D BIM model), to flag interferences, and to promote priority conversations during which walls would be designated as priority walls. Based on these commitments, specialty trades could then further detail their work plans. During construction, these meetings were 'communication central' where weekly work plans were shared and agreed upon. Although 2D drawings were used to some extent, reliance on the 3D virtual model was extensive. Figure 5 illustrates the environment in which these meetings took place.

Figure 5: Trailer Meeting (September 12, 2006)

STANDARDIZATION AND OFFSITE FABRICATION PLUS ASSEMBLY

Last but not least, thanks to effort put into detailing the design early and coordinating systems across specialist boundaries, effort put into planning and BIM development, and the willingness of team participants to assess the need for priority walls, the specialty contractors could easily visualize how to best conduct their work. For example, the mechanical contractor was able to standardize the 'handed-ness' of variable air volume boxes (VAV boxes); furthermore, they could pre-assemble larger modules of ductwork off-site, while knowing no obstructions would prevent them from rolling materials-handling carts from point-of-delivery to point-of-installation or impede installation work. This yielded significant productivity gains. The mechanical contractor reported employing on the order of 30% less manpower on site. Gains were not uniform across the board however: the mechanical contractor's shop labor hours increased and the drywall contractor suffered from worse-than-estimated productivity. However, the overall production system was remarkably more efficient, because of better design and planning, as well as the reduction in variation of work flow patterns. The incentive sharing plan was construed exactly to compensate and reward parties for such contributions and sacrifices.

CONCLUSIONS

As building systems become increasingly complex, better management practices are needed to deliver them. These practices must involve many parties, as was the case on the Camino project, where MEP and drywall contractors had to have priority conversations. The implementation of the priority wall designation for certain walls is in-and-of-itself not a unique practice for trade coordination, though it may not be known under that name. What led this practice to be successful on the Camino project was its use in combination with other practices as described in this paper: the willingness of all parties to actively participate in this learning experiment, use of an incentive sharing plan, collocation of detailing specialists in the Big Room, use of BIM, effort put into creating reliable plans, and standardization combined with off-site fabrication and assembly.

Project participants were able to have priority conversations earlier on in the project than would normally be the case, thanks to the use of the Big Room, BIM tools, and reliable planning. The incentive plan goes much beyond filling the many gaps that are left when a divide-and-conquer approach is used in setting up work breakdown structures and contracting out work; it offers an incentive to project participants to give and take with the 'good' of the project in mind. What was perceived on this project to be sacrifice for the greater good (relative to historic performance) in particular by the drywall contractor, on future projects should be accounted for when estimating, planning, and pricing work. In hindsight, the drywall contractor felt they deferred too much of their work on this project and incurred a bigger penalty than perhaps they should have. Rules must be articulated so that priority wall status can be designated early, coordination efforts can be explicit, and work can be structured accordingly. Work structuring agreements may then foster further priority conversations.

ACKNOWLEDGMENTS

This research benefited from early conversations on language and action with Greg Howell. Data and expert opinion were provided by many professionals working on the Camino project. We are particularly indebted to Jim Burrows (Southland Industries), Mike Enriquez (DPR), Greg Habel (DPR), Skip Miyamoto (DPR), Mark Napier (Southland Industries), and Dean Reed (DPR). This work was funded in part by industry contributions made in support of the Project Production Systems Laboratory at U.C. Berkeley. All support is gratefully appreciated.

REFERENCES

Ballard, G. (1999). "Work Structuring." *White Paper-5* (unpublished), Lean Constr. Inst., Ketchum, ID, available at http://www.leanconstruction.org/.

Birrell, G.S. (1985). "General contractor's management: How subs evaluate it." ASCE, *J. Constr. Engrg. and Mgmt*., 111(3), 244–259.

Birx, G.W. (2005). *Building Information Modeling Creates Change and Opportunity.* American Institute of Architects (AIA), BP 13.01.04. http://www.aia.org/aiarchitect/thisweek05/tw1209 /tw1209changeisnow.cfm

Burrows, J. (2006). Personal communication, Southland Industries, Inc.

CMG (2004). "CMG Prepared to Break Ground on Construction upon City Council Approval" Camino Medical Group, Mountain View, CA, press release posted on 11/23/2004 at http://caminomedical.org/news/pressrelease.cfm?EventPage=Press Release_ Detail.cfm&release_id=370.

CMG Document (not dated). Camino Medical Group, Mountain View, CA.

Crichton, C. (1966). *Interdependence and uncertainty. A study of the building industry.* Tavistock Institute, Tavistock Pubs., London.

Flores, F. (1982). Management and Communication in the Office of the Future. *PhD Diss*., Univ. of California, Berkeley, CA.

Holzemer, M., Tommelein, I.D. and Lin, S.L. (2000). "Materials and Information Flows for HVAC Ductwork Fabrication and Site Installation." Proc. 8th Ann. Conf. of the International Group for Lean Construction (IGLC-8), 17-19 July, held in Brighton, UK.

Howell, G., Macomber, H., Koskela, L., and Draper, J. (2004). "Leadership and Project Management: Time for a Shift from Fayol to Flores." *Proc. 12th Ann. Conf. of the Int'l. Group for Lean Constr.*, Elsinore, Denmark.

Hurley, G. (2006). "Objectives of the Report on Building the Camino Medical Project Virtually." DPR Company Presentation, 18 May, Palo Alto, CA.

Khanzode, A., Fischer, M., and Reed, D. (2005). "Case Study of the Implementation of the Lean Project Delivery System (LPDS) using Virtual Building Technologies on a Large Healthcare Project." *Proc. 13th Ann. Conf. of the Int'l. Group for Lean Construction*, Sydney, Australia. 153-160.

Korman, T., Fischer, M., Tatum, C.B. (2003). "Knowledge and Reasoning for MEP Coordination." *J. Constr. Engrg. and Mgmt*., ASCE, 129 (6), 627-634.

Korman, T. and Tatum, C.B. (2006). "Prototype Tool for Mechanical, Electrical, and Plumbing Coordination." *J. Computing in Civ.. Engrg.*., ASCE, 20 (1) 38-48.

Koskela, L. (1992). "Application of the New Production Philosophy to the Construction Industry." *Tech. Report No. 72*, CIFE, Stanford Univ., CA, September, 75 pages.

Koskela, L. (2000). An Exploration towards a Production Theory and its Application to Construction. *PhD Diss.*, VTT Pub. 408, VTT Building Technol., Espoo, Finland. 296 pp.

Lean (2007). Definition from http://www.lean.org/WhoWeAre/NewsArticleDocuments/ key_lean_ definitions.html visited 3/1/07.

Lichtig, W.A. (2005). "Sutter Health: Developing a Contracting Model to Support Lean Project Delivery", *Lean Construction Journal*, April 2005

Lichtig, W.A. (2006). "The Integrated Agreement for Lean Project Delivery." *Construction Lawyer*, 26 (3) Summer, American Bar Association, 8 pp., available at http://www.mhalaw.com/mha/newsroom/articles/ABA_IntegratedAgmt.pdf.

Macomber, H. (2004). "Projects Are Networks of Commitment." May 26, Posted at http://www.reformingprojectmanagement.com/2004/05/26/352/s

Napier, M. (2006). Personal communication during site visit of Camino Medical Project.

Neenan, D. (1999). Personal communication, Denver, CO.

Riley, D.R. and Sanvido, V.E. (1995). "Patterns of construction-space use in multistory buildings." *J. Constr. Engrg. and Mgmt.*, ASCE, 121(4), 464–473.

Riley, D. and Sanvido, V. (1997). "Space planning for mechanical, electrical, plumbing, and fire protection trades in multi-story building construction." Anderson, S. (ed.), *Proc. Constr. Congr. V*, ASCE, 102-109.

Staub-French, S. and Khanzode, A. (2007). "3D and 4D Modeling for Design and Construction Coordination: Issues and Lessons Learned." http://www.itcon.org/ data/submissions/att/a4a8.content.04194.pdf#search=%22drywall%20installation%20MEP%20coordination%22, January 28, 2007.

Tanaka, T. (2005). "Quickening the Pace of New Product Development." QV System, Inc., 9 pp., available at http://www.toyota-engineering.co.jp/Quickening%20the%20pace%20of%20New%20Product%20Development-3.pdf

Tao, W.K.Y. and Janis, R.R. (2001). *Mechanical and Electrical Systems in Buildings*. Prentice Hall, Columbus, OH.

Tatum, C.B. and Korman, T. (2005). "Coordinating Building Systems: Process and Knowledge." *J. Arch. Engrg.*, ASCE, 6 (4), 116-121

Tommelein, I.D., and Ballard, G. (1997). "Coordinating specialists." *Tech. Rep. 97-8*, Constr. Engrg. and Mgmt. Program, Civ. and Envir. Engrg. Dept., Univ. of Calif., Berkeley, CA.

Tommelein, I.D., Riley, D., and Howell, G. (1999). "Parade Game: Impact of Work Flow Variability on Trade Performance." *J. Constr. Engrg. and Mgmt.*, ASCE, 125(5), 304-310.

Tsao, C.C.Y. and Tommelein, I.D. (2007). "Work Structuring in Lean Construction: Case Study of Assembled-to-Order Light Fixtures." *J. of Constr. Engrg. and Mgmt.*, ASCE, in review.

Tsao, C.C.Y., Tommelein, I.D., Swanlund, E., and Howell, G.A. (2004). "Work Structuring to Achieve Integrated Product-Process Design." *J. of Constr. Engrg. and Mgmt*., ASCE, 130 (6) 780-789.