PULL PLANNING AS A MECHANISM TO DELIVER CONSTRUCTIBLE DESIGN

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ABSTRACT

The team at Lucile Packard Children's Hospital Expansion project adopted the pull planning process as a mechanism for collaboration between the design team and the construction team to prepare a constructible set of design drawings that would curb any post-permit design changes due to cost, constructability or coordination issues.

Pull planning helped the team come up with a process that was comprehensive, transparent, flexible and collaborative and eliminated overproduction. This process was a new way of planning for the team members. A process that was initially perceived as "stating the obvious" soon turned out to be a process that helped discover misinterpretations of scopes of work between the team members. It became a tool to define who is supposed to do what, and when, and a tool to track commitments, and to ensure all prerequisites are identified.

The plan-do-check-act cycle of pull planning demanded continuous involvement of team members which was resource intensive. The team was gradually able to attain a balance between the necessary level of detail in the pull plan and the collaboration time required.

KEYWORDS

Collaboration, Pull, Commitment, Visual Management, Transparency, Over-Production, Flexibility

INTRODUCTION

The Lucile Packard Children's Hospital (LPCH) located at the Stanford University campus in California is expanding to address the growing community needs for specialized healthcare. The proposed $510 million quaternary care facility is a 144 bed, 760,901 square feet (including underground parking) building, which features state-of-the-art medical treatment and research capabilities. The project had a one and half year preconstruction and planning phase, which began in November 2010. The project is scheduled to complete construction in mid-2016. The project timeline shown in Figure 1 gives an overview of the sequence of events for the project and details the type of collaborative activities that have occurred so far in the co-location facility called the "Integration and Collaboration Centre" (ICC).

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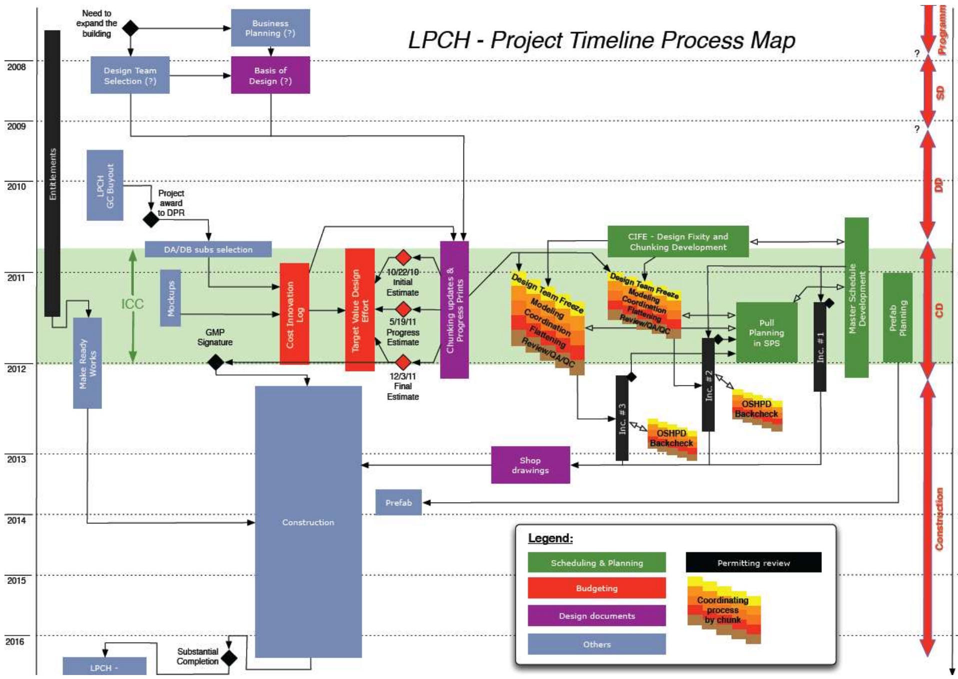

Figure 1: LPCH Expansion – Project Timeline and Process Map

The project team consisted of seven design and 15 construction companies that were co-located in the ICC and another 20 design consultant companies that were indirectly involved in the project. It is a common practice in the construction industry for the contractors to get involved on a project after getting a permit for the design. The permitted design in this case often has to go through appreciable changes during construction because of cost and constructability issues which can be very costly. The permitting agency for this project is California Office of State-wide Health Planning and Development (OSHPD). To get design changes approved by OSHPD post permit can often be very long and drawn-out and can bring uncertainty to the construction schedule. In order to minimize design changes post permit or during construction, this co-located team of design and construction companies was setup to deliver cost effective, coordinated and constructible design for permit and construction.

At the beginning of the project, DPR participated in a series of workshops with the owner and design team to define the overall Project Goals, Processes and Team setup. Through these workshops two important concepts were identified which were the basic building blocks of planning and production: Establishing a culture of signoff and Chunking.

1. ESTABLISHING A CULTURE OF SIGNOFF: ELIMINATING REWORK

The project team had a goal of adopting a lean workflow during preconstruction by minimizing rework in design and coordination. To achieve this goal, it was decided that no construction modelling and coordination would happen in an area without owner signoff and design signoff. The team decided that any area that was to be handed over from the design team to the construction modelling and coordination team had to go through a series of signoffs before being incorporated into the permit set. This series of signoffs was:

User group signoff → Owner signoff → Architectural freeze → Structural freeze → MEP and low voltage freeze →Construction Modelling and Coordination Signoff →OSHPD drawing package production from 3D model (flattening).

The cost feedback to the design preceded this process by a couple of months, and was maintained through a "cost innovation log" (CIL). Changes triggered by CIL items were addressed by the design team before the design was frozen for the chunk. Till date, CILs eliminated $37 million from the initial estimate with minimal rework in modelling and coordination.

To promote a common understanding across the team on the meaning of "signoff", series of meetings were held to define it for various disciplines.

2. CHUNKING: PLANNING THE FLOW OF WORK

Chunking is a process through which the entire facility is broken down into smaller areas (referred as "chunks"), which serve as information handover packets for the different stages of signoffs that guides the team to work their way through the entire building. This helped in maximizing the overlap of the work between the team members while avoiding rework and streamlined the workflow through the entire building.

To chunk the building, the team considered three aspects of the space. One: the function and complexity of the area. Two: the optimal area that can be handed over from one design discipline to another in two weeks. And third: the optimal area that the construction modelling crew can populate and coordinate in two weeks. The size of the chunks varied from 60,000 square feet in the less complex parking garage to 20,000 square feet in more complex operating rooms space.

It is noteworthy that the project was at 100% design development stage before the chunking concept was executed. Therefore, the overall systems design was already completed. The concept of chunking did not drive how the building should be designed, but how the design freeze should happen and be handed over for construction modelling and coordination process. Chunking laid the backbone for how the design of this large facility would be vetted for coordination and constructability to the level of detail of 0.25 inches. Figure 2 shows an example of how the basement level was chunked.

The team developed a "model chunking and design fixity matrix" (referred to generally as the "fixity matrix") to reflect the concepts of chunking and signoff. The fixity matrix represented when a particular area was supposed to go through the various steps of signoffs and the sequence of chunks in which production work was happening through the building. This matrix established the baseline schedule for the process. A visual of this matrix is shown is Figure 3 below.

Before pull planning was implemented on the project, the team felt comfortable using the fixity matrix as a planning and production tool, because it told each and every project participant on when they were supposed to do what.

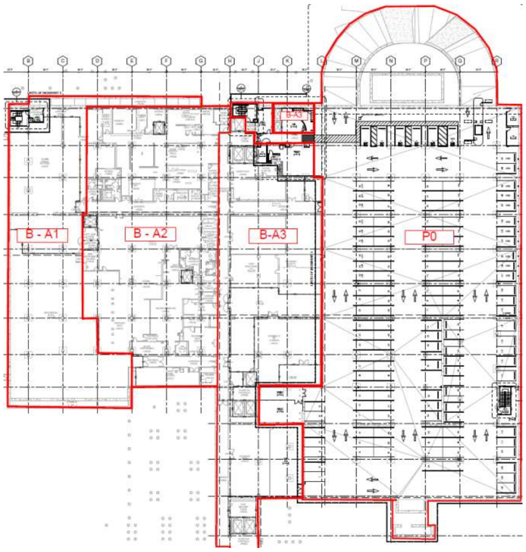

Figure 2: Chunking Plan for the Basement Floor

Lucile Packard Children's Hospital AT STANFORD

Milestones Achieved	At Risk		Dated:

LPCH EXPANSION - PHASE II - DESIGN FIXITY DATES and MODEL CHUNKING

				DESIGN FREEZE DATES								
Interiors Team	Chunks	RTKL ASE Package Date	LPCH Signoff	Architectural	Structural	MEP Freeze	AEC Coord (ends with model start)	Modeling Complete	95% Model Coord. Complete (BASELINE)	95% Model Coord. Complete (PROJECTED /ACTUAL (SIGNOFF)	% Achieved at Coord. Complete	Final Flattened Model to Design Team (Baseline)
Team A	Roof - Area 03		2/7/2011	1/21/2011	1/28/2011	2/4/2011		2/18/2011	3/4/2011	3/4/2011	100%	
Team A	Roof - Area 01		2/7/2011	2/4/2011	2/11/2011	2/18/2011		2/25/2011	3/11/2011	3/11/2011	98%	
Team A	Vertical Coordination (shafts)		2/7/2011	Final Coord. and signoff by chunks. Prelim. modeling and coord. done by 3/18								
Team B	Parking Garage - P1A	2/24/2011	2/7/2011	2/11/2011	2/18/2011	2/25/2011		3/18/2011	3/25/2011	8/5/2011	86%	
Team A	Roof - Area 02		2/7/2011	2/18/2011	2/25/2011	3/4/2011		3/11/2011	4/1/2011	4/1/2011	95%	
Team A	Basement - Area 01	2/24/2011	2/7/2011	3/4/2011	3/11/2011	3/18/2011		4/1/2011	4/15/2011	10/14/2011	85%	
Team A	Basement - Area 02	2/24/2011	2/7/2011	3/11/2011	3/18/2011	3/25/2011		4/15/2011	4/29/2011	5/13/2011	91%	
Team B	Parking Garage - P1B	2/24/2011	2/7/2011	3/18/2011	3/25/2011	4/1/2011		4/15/2011	4/29/2011	4/29/2011	99%	
Team A	Basement - Area 03	2/24/2011	2/7/2011	4/1/2011	4/8/2011	4/15/2011		4/29/2011	5/13/2011	5/27/2011	98%	
Team A	Level 01 - Area 02	3/10/2011	2/7/2011	4/8/2011	4/15/2011	4/22/2011		5/13/2011	5/27/2011	12/1/2011	92%	
Team B	Parking Garage - P0	2/24/2011	2/7/2011	4/15/2011	4/22/2011	4/29/2011	5/13/2011	5/27/2011	6/10/2011	6/17/2011	95%	
Team A	Level 01 - Area 03	4/12/2011	2/7/2011	4/29/2011	5/6/2011	5/13/2011	5/27/2011	6/10/2011	6/24/2011	12/1/2011	92%	
Team A	Ground Floor - Area 01	4/12/2011	4/22/2011	5/6/2011	5/13/2011	5/27/2011	6/10/2011	6/24/2011	7/8/2011	11/1/2011	92%	
Team B	Parking Lot Items - Roof		2/7/2011	5/27/2011	6/3/2011	6/10/2011	6/24/2011	7/1/2011	7/8/2011	7/28/2011	100%	9/2/20

Figure 3: Model Chunking and Design Fixity Matrix

CHALLENGES WITH THE FIXITY MATRIX

The team started to work based on the fixity matrix, as they got into more complex chunks like the basement mechanical spaces, the deliverables were not being met on the target dates set in the fixity matrix. In order to meet the deliverables, delivery dates were being pushed out which subsequently affected the OSHPD increment submission date. This was a big issue as another project goal established was "zero tolerance on major milestones." Through a quick root-cause analysis, the team identified that there were quite a few problems with the fixity matrix:

1. The matrix did not help identify all the constraints that needed to be resolved to meet the design freeze deliverable dates. These atypical constraints specific to the function of a chunk were not identified from the design freeze definitions that adopted a more general approach.
2. The fixity matrix was rigid. If one date was pushed, the end date was pushed too. The team needed a work plan that was more flexible.

The matrix was linear, and did not take into account the iterative and collaborative nature of the design process.

The fixity matrix did not account for the actual permit drawing package preparation work that needed to happen after the last area was flattened for OSHPD. The first increment (Increment 1 – Structure Package) was delayed because of not clearly planning out the sequence of events that were supposed to happen before submitting the drawing package to OSHPD.

The project team determined that they needed a process in place to make sure they were working based on a plan that was comprehensive, transparent and flexible.

STRATEGY

Pull planning has been prevalent in the construction phase, and is considered comprehensive, transparent, and flexible. DPR proposed implementing pull planning during this preconstruction phase to help come up with a work plan that would eliminate overproduction and make it possible for the team to meet milestones.

IMPLEMENTATION

PULL PLANNING

First, the team identified major and intermediate milestones. Then, the team planned backwards from those milestones, mapping all the work required from each team member.

The basic building block of the pull planning process was "I Get-I Give" cards (Figure 5), filled out by each project participant.

These cards were used for planning and promising, and for establishing a customer supplier relationship between team members.

- Team members specified:
- What they need from others.
- What they can deliver.
- Concentrated work time.

The pull planning exercise ensured that every prerequisite or constraint identified by a "customer" had a "supplier" who promised to deliver it. All the cards that fulfilled this criterion were marked by the customer with a green dot (Figure 6), signifying a "satisfied customer". This ensured that we were coming with a comprehensive work plan. The pull planning process also fostered interaction, collaboration, and transparency, and turned out to be great team building exercise.

Every participant was asked to fill out "I Get-I Give" cards before coming to the pull plan wall. Interestingly, many of the cards were never actually affixed to the wall (Figure 7), because there was no customer for what they were delivering. In other words, many team members thought they needed to produce work which in fact had no end use. By working together to pull work from suppliers, the team eliminated potential over-production, or production of non-value work.

Figure 4: Pull Planning Sessions

Figure 5: I Get-I Give Card

Figure 6: Satisfied Customer

Figure 7: Over Production

CONTINUOUS IMPROVEMENT - COMMITMENT TRACKING AND RE-PLANNING

The team used Strategic Project Solutions, Inc. (SPS) software to capture the pull plan from the paper “I Get-I Give” notes (Figure 8). SPS turned the plan to a “living” work plan that could be used for generating the production plan, tracking commitments, and re-planning (Figure 9). This plan was revisited and modified every two weeks. SPS provided a platform that fostered flexibility in the plan, and helped the team re-plan so that major milestone dates could still be met even if the intermediate milestones and tasks were modified.

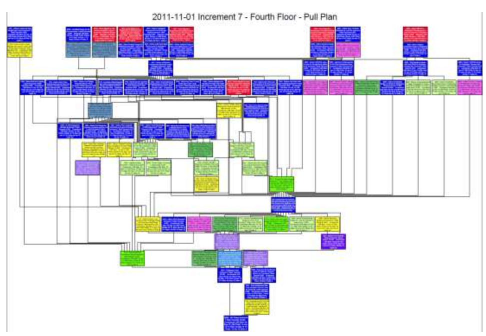

Figure 8: Pull Plan in SPS

ID	Desc	Member	LRM Dates	Production Plan Date	At Risk	Progress	Root Cause	Category	Date Compl.	Docs
423	Garage Exhaust Noise Criteria / Review Sound Treatment for Fans (PARTIAL OF TASK 41) Part 1 of 2 (Remaining Duration: 3.00D)	M_R	6 May 11 ~ 12 May 11	1 Jun 11 ~ 7 Jun 11		-- Choose --		-- Choose --		None
422	Frozen architectural documents for loading dock (PARTIAL OF TASK 94) - Part 1 of 2 (Remaining Duration: 3.00D)	M_T	6 May 11 ~ 12 May 11	1 Jun 11 ~ 7 Jun 11		-- Choose --		-- Choose --		None
110	Deliver Lighting redesign for P0 to HGA	J_A1	24 May 11 ~	1 Jun 11 ~		-- Choose --		-- Choose --		None

Figure 9: Production Planning in SPS

LESSONS LEARNED

Despite the many benefits of pull planning, there were quite a few challenges that the team faced, and some lessons learned through implementing this relatively new process during the design phase. Effective implementation of pull planning requires discipline and commitment from all team members. The following must be done on a periodic basis, at least once a week:

Generate and update production plans from the pull plan.

Re-plan. Review and update the pull plan as necessary to meet major milestone dates.

The project team was not completely aware of the time and effort that was needed in order to maximize the value of the pull plan, and resources were not planned and allocated accordingly. With the level of involvement directly proportional to the level of detail being mapped out, the design team debated between planning the work versus actually doing the work.

IDENTIFY THE RIGHT LEVEL OF DETAIL IN PULL PLANNING

Through the chunking exercise, the building was broken done into 25 chunks of approximately 20,000 square feet each. The level of detail for tasks mapped out in the pull planning process was to the level of detail of each chunk (work area). The team decided that it would be practically impossible to start the pull plan for each chunk from scratch. But there was a generic sequence of tasks that remained the same for each chunk (derived from the design fixity matrix and design freeze definitions). So, the team developed a generic pull plan that would be applicable for any given chunk and then it would be replicated for each chunk so that the production plans could be generated from this generic pull plan.

The ability to create standard work processes in SPS helped the team realize this idea. There were both pros and cons to this approach. On the positive side, it helped create production plans for each chunk and gave a mechanism to track commitments. Conversely, the generic tasks camouflaged the specific tasks that should have been mapped out to address the specific needs of each chunk. Since some of the chunk-specific tasks and constraints were not explicitly mapped out, it created holes in the work plan that surfaced after executing the production plan for a chunk.

A lesson learned is that after replicating the generic tasks for each chunk, it is important to map chunk-specific tasks and constraints at the onset of planning the work for that chunk. It is worth it to allocate appropriate resources by all team members to facilitate this approach.

ALLOCATE APPROPRIATE RESOURCES TO GENERATE & UPDATE PRODUCTION PLAN

It was not mandatory for everyone to generate and update their production plan within SPS. This meant that not enough team members adopted the tool, so DPR, as the administrator for SPS, had to generate and update the production plans for the team in SPS in the weekly commitment-tracking calls. This in turn caused a lack of ownership on the tasks by the performers, which affected efficiency. If one team member does not update their task on time, it creates a “domino effect,” pushing out the forecasted start date for each successive task. In order to successfully implement the production plan, it is critical that each team member own and update the tasks assigned to them in SPS.

HAVE A MECHANISM TO MANAGE UNANTICIPATED PLAN DISRUPTIONS

The team was not able to adapt to the changing deliverable dates because of upstream (especially indirectly related) work not being finished on time. There were quite a few "nodal" tasks that had multiple predecessors, which were intermediate milestones like the architectural freeze and MEP freeze. Through these intermediate milestones most of the information was being handed over in batches from one discipline to another. Often, the owner of these "nodal" tasks did not feel that it was warranted to change its delivery date if one of the 10 upstream tasks was not completed. The team decided not to change the deliverable date, but to modify the deliverable.

Managing these unfinished constraints in SPS without changing the intermediate milestone dates was extremely difficult. The constraints had to be unlinked from the intermediate milestone, and then relinked somewhere else in the pull plan. But, there were no logical activities to which it could be relinked. The team decided to add a "parking lot" phase, where these pending design items would be deferred to. For a large team, it turned out that it was easier, more manageable, and less confusing if the deliverable dates were not changing, and if these intermediate milestones were happening in a regimented fashion. For example, every design discipline had a chunk-specific design freeze milestone deliverable every two weeks on a Friday.

The "parking lot" was a way of managing unanticipated plan disruptions. It allowed the team to manage these disruptions all at the same time, in bulk, instead of taking a piecemeal re-planning approach for each individual disruption. The "parking lot" seemed intuitively like a less efficient approach, but proved to be more workable with a team that had not yet bought into continuous re-planning.

The solution for production planning that was finally adopted was a hybrid approach in which actual scope of work was mapped out in the pull plan, and the delivery dates were driven through the intermediate milestones in the fixity matrix. Any unanticipated disruptions to the pull plan were assigned to the parking lot phase, which was also identified in the fixity matrix.

In an ideal situation, the team would have allocated enough time and resources so that they could manage unanticipated disruptions through continuous re-planning on per-instance basis, and a parking lot would not have been needed. That way, the actual delivery date of the major milestone would have pushed further out from the last responsible moment, but would have had less impact than the addition of a parking lot phase.

Another lesson learned was that there must be a balance between the flexibility that the team desires, and the re-planning they can afford to do.

ENSURE THAT EVERYONE IS WORKING PER THE PLAN

The other challenge faced during the pull planning process was overall team participation and ownership. There were seven design companies and 20 design consultants. During the pull planning process, the primary design companies did not map out the constraints from their design consultants. The design consultants were not participating in the pull planning meetings. The time constraints for their deliverables that could have been identified through pull planning were not identified or conveyed to the consultants efficiently. Therefore, some of the 20 design consultant companies were not producing work according to the plan, and they delivered work too late for the downstream companies to incorporate that information into the design. This in turn caused the pull plan to be disrupted and rework by downstream team members. The team determined that it is essential for everyone, including the extended team who does not necessarily interact directly with the whole team, to work and deliver based on the pull plan.

PLAN FOR ITERATIONS IN THE PULL PLAN

This aspect is primarily driven from the iterative nature of design compared to linear approach of construction. On a macroscopic scale, the concept of a "parking lot" phase provided an opportunity for iteration through all the spaces, and helped the quality of the end deliverable. Along with that, the team identified a need for iteration at the chunk level in the period between the last design freeze date and model start date for a chunk—the "AEC information validation" phase.

Initially, the team did not have a period of iteration identified. The overall design team did not have a chance to review and coordinate the complete design package, so design changes were being made to a chunk while the construction models were being created and coordinated, which was not efficient. The AEC information validation phase also provided a time for contractors to validate the design information for completeness before starting on the model. Figure 10 shows where these two iterations occurred in the overall planning philosophy.

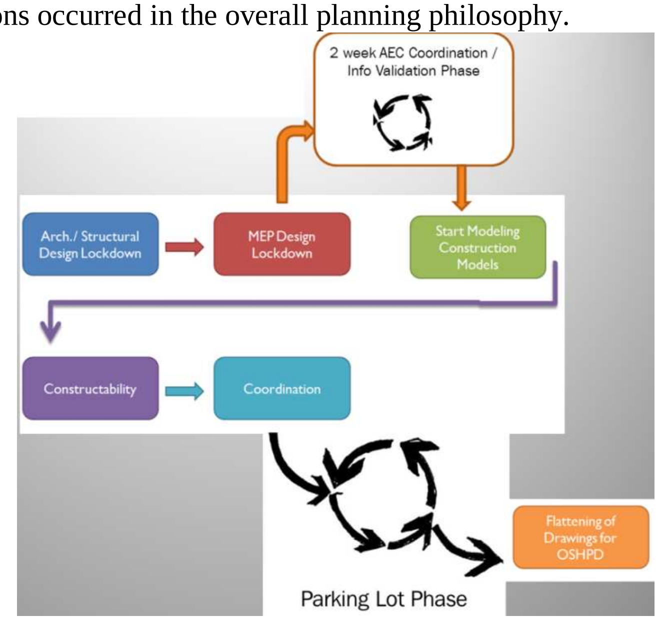

Figure 10: Plan for Iterations in the workflow

CONCLUSIONS

By implementing pull planning process, the project team was able to develop a work plan that helped achieve the end goal of submitting constructible set of design drawings to the permitting agency on time.

The process of creating the pull plan itself also provided a venue for building camaraderie, trust, and communication. Every team member came to understand what any other team member was working at any point in time. This transparency helped achieve a comprehensive plan that facilitated identifying constraints and interdependencies. Furthermore, the performers felt more invested in the plan because they had developed it themselves. After the implementation of pull planning, the remaining four OSHPD increment packages were submitted on time as planned.

Nevertheless, the project team did have a lot to learn about how pull planning should be implemented in the preconstruction phase.

First, the owner plays an important role in fostering a collaborative environment that is critical to this mode of project delivery. This is especially true if the design team and construction team do not have a direct contractual obligation to each other.

Second, project teams should plan for the adequate involvement to support continuous planning, generating and updating of production plans. The benefits of the higher upfront investment will eventually manifest itself.

Third, be disciplined of working as per the pull plan. The plan is value adding only if the production work is being generated from it. A simple directive from the owner that they would only be willing to pay for work stemming directly from the pull plan helps achieve the team participation required for this process to work.

Finally, there is a scope for improvement and development of tools that support continuous planning processes like the one adopted on this project.

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REFERENCES

Ballard, G. (1994). "The Last Planner." Northern California Construction Institute, Monterey, CA, April 22-24.

Ballard, G. (1997). "Look ahead planning: the missing link in production control." *Technical Report No. 97-3*, Construction Engineering and Management Program, Civil and Environmental Engineering Department, University of California, Berkeley, CA

Choo, H.J. and Tommelein, I.D. (2001). "Requirements and barriers to adoption of last planner computer tools." IGLC 9.

Chua, D.K.H., Jun, S.L. and Hwee, B.S. (1999). "Integrated production scheduler for construction look-ahead planning." IGLC 7.

Liker, J.K. (2004). *Toyota Way: 14 management principles from the world's greatest manufacturer.* McGraw-Hill, New York.

Tommelein, I.D. and Ballard, G. (1997). "Coordinating Specialists." *Technical Report No. 97-8*, Construction Engineering and Management Program, Civil and Environmental Engineering Department, University of California, Berkeley, CA

Tommelein, I.D. and Ballard, G. (1997). "Look-ahead Planning: Screening and Pulling." *Technical report no. 97-9*, Construction Engineering and Management Program, Civil and Environmental Engineering Department, University of California, Berkeley, CA.