IS THE LAST PLANNER SYSTEM APPLICABLE TO DESIGN? A CASE STUDY

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ABSTRACT

The Last Planner™ system has been successfully implemented in construction to increase the reliability of planning, improve production performance, and create a predictable workflow. However, some practitioners question the function of the Last Planner™ system during design especially that design processes involve iterations and circular chains of interaction between different parties. The purpose of this paper is to report on research comprising the application of Last Planner™ system in design. The paper describes the developments and adjustments introduced to the Last Planner™ system to better suit design processes on a health care project in North America. Novel standardized planning practices used on the project are reported and analyzed. The study findings suggest that the Last Planner™ system principles account for both deliberative and situated action models. On one hand, deliberative planning[4] takes place at the master and phase scheduling level where a premeditated rigid course of action is undertaken in setting milestones and identifying handoffs. On the other hand, situated planning is performed at the lookahead planning and weekly work planning stages where planning takes into account changes in the environment and the uncertainty affecting inputs, processes, and outputs of design activities.

KEY WORDS

Lean design, last planner™ system, lookahead planning, production control, lean construction.

INTRODUCTION

Processes in the Architecture, Engineering, and Construction (AEC) industry are inherently variable and uncertain. Variability undermines project performance and disrupts workflow

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manifesting itself in detrimental project consequences on cost, duration, and quality. Design processes are not foreign to high uncertainty and often encompass circular rather than linear chains of interaction between different parties (Crichton 1966, Nahmias 2009, Hamzeh et al. 2007).

Hopp and Spearman (2008) highlight two types of variability in a manufacturing production setting: (1) process time for a task executed at a workstation and (2) the rate of task arrival at a workstation. In construction, various types of variability, including those mentioned by Hopp and Spearman, impact task workflow and impose a challenge to project teams in managing workflow especially during design which comprises iterative processes fluctuating between the owner's value preposition and various design alternatives (Ballard 2000b and Ballard 2002).

The quest to reduce the negative impacts of variability and increase the reliability of workflow has lead to the development of the Last Planner^{TM} system (LPS) for production planning and control. This system has been successfully implemented on construction projects to increase the reliability of planning, improve production performance, and create a predictable workflow (Alarcon 1997, Tommelein and Ballard 1997, Ballard and Howell 2004, Ballard et al. 2007, Gonzalez et al. 2008).

Design involves both positive iterations that help improve product quality and negative iterations that do not add value and are therefore wasteful. However, it is difficult to foresee negative iterations and weed them out during the planning process. In fact, design comprises complex tasks that entail reciprocal interdependencies and require the sharing of incomplete information (Ballard 1999 and Ballard 2000b).

Ballard et al. (2009) highlight three main factors that distinguish production control during design: (1) greater uncertainty of ends and means reducing the ability to foresee the sequence of future tasks, (2) the impact of increasing execution speed of design tasks on removing constraints and making tasks ready for execution, and (3) interdependencies between design tasks that increase work complexity and the planning functions.

Taking into account the challenges mentioned above, the Last Planner^{TM} system advocates the following planning practices: (1) plan in greater detail as you get closer to performing the work , (2) develop the work plan with those who are going to perform the work, (3) identify and remove work constraints ahead of time as a team to make work ready and increase reliability of work plans (4) make reliable promises and drive work execution based on coordination and active negotiation with trade partners and project participants, and (5) learn from planning failures by finding the root causes and taking preventive actions (Ballard 2000, Ballard et al. 2007, Ballard et al. 2009).

Despite the previous applications of LPS during design, the implementation process is still unclear and not elaborately documented. In fact, many questions were raised about LPS implementation during design at the Lean Design Forum held at UC Berkeley in January 2009. This paper presents a successful implementation of the Last Planner^{TM} system at the Cathedral Hill Hospital (CHH) Project in San Francisco, California. It reports results of research conducted through the Project Production Systems Laboratory (P^2SL) at University of California-Berkeley on planning processes during the design phase at CHH and lays out an elaborate contextualization of the process in an integrated lean project delivery setting.

METHODOLOGY

This paper reports the implementation process of the LPS at CHH as a reference for industry practices and basis for continuous improvement. The study was performed in an "action research" environment where the first author have actually joined the project as a team member, gathered empirical data, analyzed and evaluated the data with the team, searched for useful patterns or variations, developed various improvement alternatives, and tested these improvements empirically.

The case study research method was adopted in this study for the following purposes: (1) it is an appropriate strategy for answering questions pertaining to 'how' and 'why' when no control for behavioral events is required and when research focuses on contemporary affairs, (2) it uses both quantitative and qualitative methods to explain phenomena, (3) it can employ quantitative methods to explain questions, (4) it uses real-life evidence and observational richness to describe relationships, (5) it utilizes multiple sources of evidence in a natural setting that encompasses temporal and contextual facets of the variables monitored, (6) it uncovers the dynamics of events explaining the phenomenon under study, (7) it can employ rigorous evidence collection, description, observation and triangulation, (8) it provides qualitative understanding when arriving at conclusions and analyzing results (Meredith 1998, Stuart et al. 2002, Yin 2003).

Although this study highlights advanced industry practices for implementing the last planner system during design, results of this study are bounded by the limits of generalizability and are not necessarily applicable to all construction projects.

CASE STUDY BACKGROUND

The $1.7 Billion Cathedral Hill Hospital project in San Francisco has become a cutting edge laboratory for implementing lean integrated project delivery (IPD). Fostered by an integrated form of agreement (IFOA) where all project participants share rewards and losses, the project can be considered a good model for successful implementation of target value design, the last planner system during design, building visualization, collaborative and set-based design, problem solving, and built-in quality,

Cathedral Hill Hospital (CHH) is a proposed 16-story 555-bed women and children hospital project in San Francisco, California. The project's design was validated in 2007 and the hospital, is intended to commence services on January 1st 2015.

Sutter Health and CPMC, the owner, assembled a preconstruction team to perform design validation, collaborate during design development, and lead the project into the construction phase. The owner opted for an integrated form of agreement and integrated project delivery with lean implementation. IFOA and IPD align stakeholder interests, improve project performance, share risks and rewards, and maximize value for designers, builders, owner, and users. Initially, the owner (CPMC and Sutter Health), the architect (Smith Group), and CM/GC (Herrero-Boldt) signed the agreement; but later on, the rest of the project parties also signed as they joined the project (Lichtig 2006).

The project was accepted for phase plan review (PPR) by the Office of Statewide Health Planning and Development (OSHPD). The process engages OSHPD in reviewing design in a phased manner during design conceptualization, criteria design, detailed design, implementation documents, agency review, construction, and closeout.

The early Integrated Project Delivery (IPD) team included various project stakeholders: the owner, healthcare providers, operations staff, architects, engineers, specialty consultants, the general contractor, and major sub-contractors called trade partners as per the project agreement. Cross functional teams or clusters involving specialists from various organizations having different design and construction backgrounds were established to improve the quality of design and increase coordination. A core group of top executives from owner, architect, and construction manager/general contractor is responsible for making major decisions on the project after consulting with (IPD) and evaluating results of the A3 (problem solving) process.

To maximize value delivered on this project and continuously reduce waste, a “lean project delivery” approach was adopted in conjunction with Sutter’s “Five Big Ideas” that emphasize: (1) increasing the relatedness among IPD team members, (2) improving collaboration between project participants during all project phases, (3) managing the project as a network of interrelated commitments, (4) looking beyond local optimization to optimizing the whole, and (5) promoting organizational learning from the collective experience to drive continuous improvement (IFOA 2007).

As a production planning and control system, the Last Planner System™ was implemented on the owner’s request to include the following: “a milestone schedule, collaboratively created phase schedules, make-ready look ahead plans, weekly work plans, and a method for measuring, recording, and improving planning reliability” (IFOA 2007).

DESIGNING THE PLANNING PROCESS AT CHH

The planning process was designed with the following goals in mind: (1) to integrate planning processes within clusters and among clusters, (2) to layout a road map for a successful implementation of LPS, and (3) to synergize input from all project stakeholders. A transition team, entrusted with developing a new process model, was charged with assessing the current implementation of the last planner system, recommending potential adjustments, developing a new process, identifying training necessities, developing training programs, and planning a deployment scheme.

The team investigated several development areas related to the current implementation of the last planner system including: (1) cluster involvement, (2) mid-level planning (phase scheduling and lookahead planning), (3) information flow, (4) constraint analysis, (5) root cause analysis, (6) first run studies, (7) standardized planning tasks for cluster planning and IPD team sessions, (8) daily huddles, and (9) deployment of the new process. The team recommended improvements to the current process and later incorporated all improvements into a new planning process.

The transition team recognized the need to conduct training sessions for CHH preconstruction staff in lean methods in general and the last planner system in particular. Accordingly, the team created a training program to teach various aspects of lean theory, techniques, and tools. The program includes four main sections: (1) introduction to lean history, concepts, and methods, (2) basic training modules, (3) lean project delivery, and (4) lean management.

The basic training modules, produced and taught by coaches from the IPD team, include: (1) value stream mapping, (2) five S (sort, set in-order, shine, standardize, sustain), (3) reliable promising, (4) learning from experiments, (5) learning from breakdowns, (6) choosing by advantages, and (7) A3 problem solving reports.

The lean project delivery section was developed with Professor Glenn Ballard and incorporates examples and applications from the preconstruction phase at CHH. This section includes: (1) the last planner system, (2) target value design, (3) design management, (4) supply chain management, and (5) design of construction operations.

The lean management training target all team supervisors and introduces essential tools for team leaders including: leader’s standard work, daily accountability processes, visual controls, developing people, leading change, problem solving/ process involvement, and lean management system assessment (Hamzeh 2009).

THE PLANNING PROCESS

In designing the new planning process, the transition team had to tailor the last planner system to the specific needs, conditions, and challenges of the CHH project taking into account (1) the specific nature of design (high uncertainty in design tasks, iterations, incubation time for design development, limited lead time to remove constraints), (2) the need for a standardized process to cover various disciplines and clusters, and (3) the limited previous experience of project partners with implementing lean and the last planner system.

PROCESS MAP

The transition team used process mapping laying out the planning-process goals, steps, and responsibilities. After mapping the process, the team consulted higher management and incorporated their feedback. Figure 1 shows the planning process designed for CHH during preconstruction.

The process starts with the master schedule which is used as a basis for delivering the project delivery and meeting milestones. It contains major project milestones including: entitlements, submittal of first design increment to OSHPD, submittal of second design increment, submittal of third design increment, start of demolition, start of construction, and commissioning of hospital operations.

As shown in figure 1, the first step is identifying a milestone to map and highlighting the deliverables to release when the milestone is complete. However, it is crucial at this stage to align the perspectives of various project partners for each milestone that needs to be mapped. Accordingly, a 'milestone alignment' step involving all project stakeholders is helpful in unifying the team's expectations to value required to deliver when executing this milestone.

'Milestone alignment' starts by identifying the interim and the end customer for each deliverable and expressing the outcomes of each deliverable for interim customers along the value chain. A deliverable, for example, might be "fire and life safety plans" for OSHPD who are the final customer of this phase. Interim customers can be the architect, the mechanical consultant, the mechanical contractor, the fire life and safety consultant, etc. Defining the outcomes of each deliverable goes in parallel with expressing and communicating to team the conditions of satisfaction for an upstream partner to meet when delivering to another project partner downstream. When a clear understanding of milestone deliverables is achieved, the team is ready to move to next stage of "phase / pull scheduling".

"Phase / pull scheduling" is a collaborative process that a team can use to plan the delivery of a milestone according to customer pull or value expectations (Ballard 2000a). Since milestones are expressed in concrete deliverables during "milestone alignment", phase scheduling sessions can be conducted in smaller groups to increase the productivity of these sessions. That is why phase scheduling sessions are conducted on a cluster-by-cluster basis though involving participants from other clusters who attend and provide input.

Cluster phase sessions start by breaking the milestone or the deliverable to be mapped into constituent activities. This is followed by assigning durations and prerequisites for activities. Team members write this information on cards and post them on a wall. The next step, reverse phase scheduling, involves scheduling these constituent activities starting backwards from the milestone towards the start. Backward scheduling is helpful in uncovering constraints because it forces team members to think of all prerequisites required to start an activity (Ballard 2000a).

The reverse phase schedule might result in surpassing the start date. When this happens, re-planning is required to fit the schedule into the available time frame. This exercise produces a cluster phase schedule with one of the following characteristics: (1) an adjusted schedule with some float that can be redistributed to uncertain and crucial activities, (2) an adjusted schedule that just fits the time frame, or (3) an adjusted schedule that does not meet the allotted time frame. In the third case, the milestone should be updated to reflect the actual time frame.

After completing various cluster phase schedules, cluster groups conduct an IPD planning session to coordinate their schedules and activities spanning more than one cluster. Prior to the meeting, each party identifies their activities, durations, constraints, and responsibilities. During the meeting, each party communicates his/her requests to remove constraints, expresses conditions of satisfaction, and obtains commitments to release these constraints. At the end of this exercise, the product is a coordinated IPD phase schedule ready for execution. It is recommended that phase / pull scheduling starts long-enough prior to the beginning a milestone to accommodate the team's input.

Transferring the phase schedule into production schedule starts with "lookahead planning" when each cluster leader or a designated project engineer filters a six-week lookahead from the phase schedule and works with team members for evaluation and planning. Prior to a weekly cluster meeting, each project partner studies his/her tasks, breaks them down to the level of operations, sequences operations, assigns durations, allocates resources, and identifies constraints required to be removed to complete tasks. The cluster then meets, plans next week's work, discusses constraints, identifies first run studies, and indentifies intra-cluster constraints. The resultant lookahead schedule is later used as a guide for weekly work planning. This is the first step in situated planning.

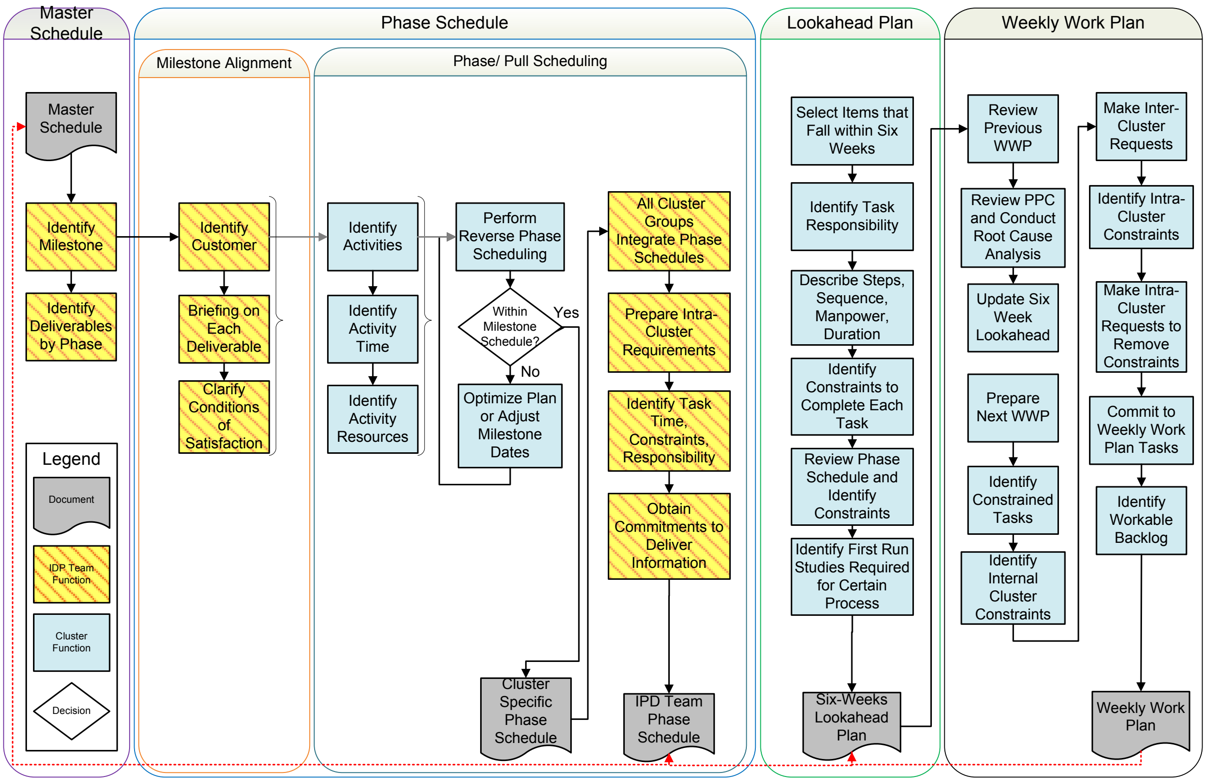

Figure 1: Process Map Depicting the Planning Processes at CHH (Modified from The Last Planner Handbook at CHH, 2009)

Another step in situated planning involves developing the "weekly work plan" based on the previously developed six-week lookahead plan. Each cluster meets weekly to report progress on last week's plan and produce next week's work plan. Reporting progress involves evaluating planned percent complete (PPC) to measure work accomplished versus planned. Incomplete tasks undergo root-cause analysis to uncover the root cause for non completion and develop preventive actions to inhibit the same failure from recurring.

Preparing the next week's work plan, requires discussing constrained tasks, putting forward requests to other last planners to remove constraints, and making activities ready by removing constraints. Intra-cluster constraints are also identified and requests for removal are formulated. At this stage, cluster last planners are in a good position to commit to next week's work plan and place some non-critical activities on the workable backlog to be performed should extra capacity be available. The weekly work plan is a living document that is modified during the week and used as a management tool.

SCHEDULE DEVELOPMENT

Figure 2 shows a layout of the four planning processes that form the last planner system. The first process is master scheduling which incorporates owner's expectations, logistics plans, and work strategies into a master schedule. The master schedule presents milestones and phase level activities. Phases are represented by boulders to characterize coarse level of detail involved.

The second step "milestone alignment", aligns stakeholder expectations for the milestone in question and is a preparatory step for "phase / scheduling". "Phase / scheduling" involves the following steps: (1) breaking down a milestone or phase represented by a boulder into constituent processes represented by rocks, (2) reverse phase scheduling, and (3) readjusting the schedule to meet the allotted time frame.

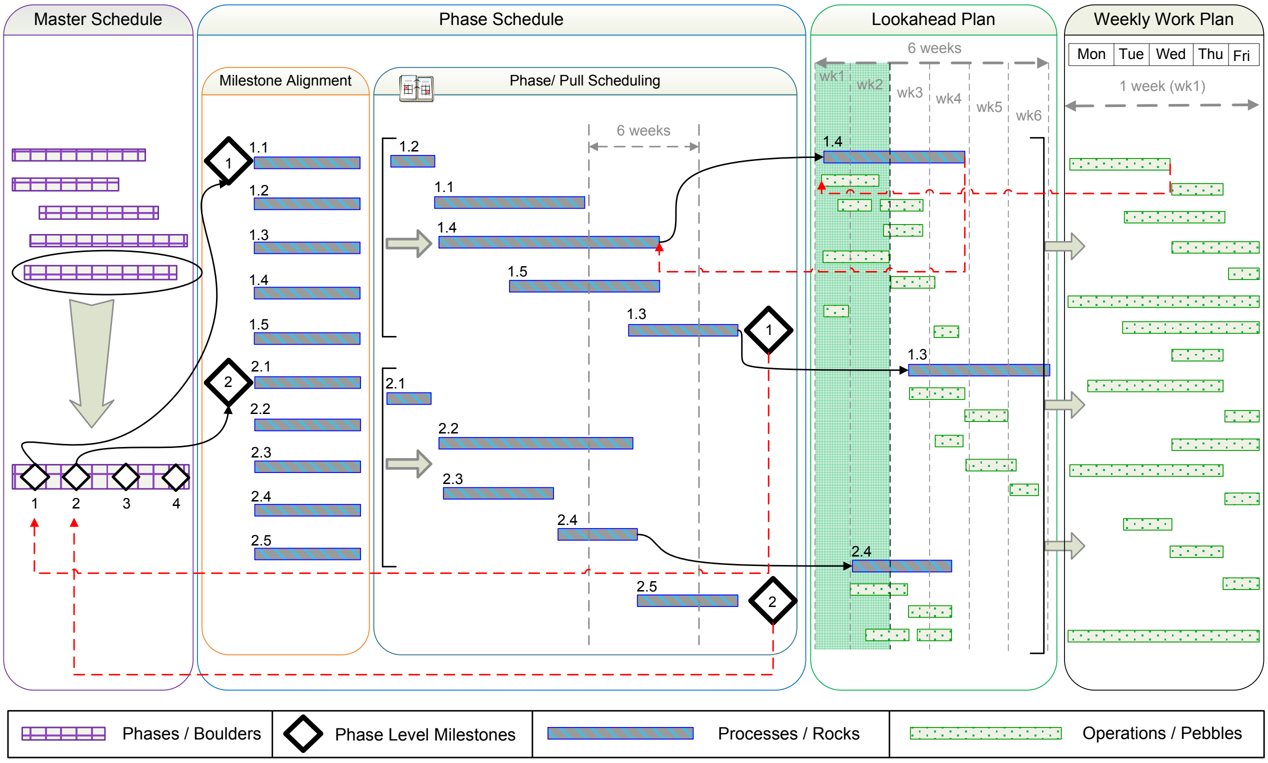

Figure 2: The LPS Scheduling Development Model at CHH (Hamzeh 2009)

At CHH, the master scheduler built the master and phase schedule in Primavera P6. After bi-weekly updating the schedule in P6, he extracts a six-week filter and forwards it to individual clusters to perform lookahead planning and to build weekly work plans. Lookahead planning involves (1) breaking down processes represented by rocks into operations represented by pebbles, (2) sequencing operations and allocating resources, (3) identifying/removing constraints, (4) designing operations, and (5) identifying the need for first run studies.

The lookahead planning process produces a detailed two-week lookahead backlog of constraint-free tasks and constrained tasks that can be made ready during the week. The weekly work plan is then developed from this backlog by moving critical tasks and made ready tasks into next week's work plan. Non-critical tasks join the workable backlog to be performed in case of extra capacity.

Two metrics are used to measure the performance of lookahead planning: (1) Tasks Anticipated (TA) and (2) Tasks Made Ready (TMR). TA measures the percentage of tasks anticipated on the lookahead schedule one week or two weeks ahead of execution. TMR measures the performance of lookahead planning in identifying and removing constraints to make tasks ready for execution (Hamzeh et al. 2008).

Developing the "weekly work plan" involves various planning functions: (1) advancing tasks that are well defined, constraint free, properly sequenced, well sized (in terms of load and capacity), (2) performing collaborative weekly work planning, (3) exercising reliable promising, and (4) learning from plan failures (Ballard 2000a).

INFORMATION FLOW

The new planning process requires designing transparent pathways for information flow. Figure 3 presents a model mapping information flow between pull /phase scheduling sessions, cluster group meetings, and IPD team planning meetings.

Before the beginning of a phase, each individual cluster group meets and develops a phase schedule. The master scheduler incorporates phase schedules into the master schedule which is built in Primavera P6 and updated biweekly in a meeting involving cluster-group representatives. A six-week lookahead is filtered from the master schedule and sent through the planning facilitator to cluster leaders or project engineers who in turn filter tasks by discipline and forward them to the designated project parties (The Last Planner Handbook at CHH, 2009).

In their respective weekly meetings, individual cluster groups perform lookahead planning, develop weekly work plans, and indentify constraints. In IPD weekly team meetings, each cluster leader reports last week's progress and intra-cluster requests to remove constraints. Constraint removal and planning issues raised during these meetings are then incorporated into the master schedule and the cycle starts again. The planning facilitator is monitoring the overall process, assisting in pull sessions, and overlooking team meetings to insure smooth information flow and proper team planning.

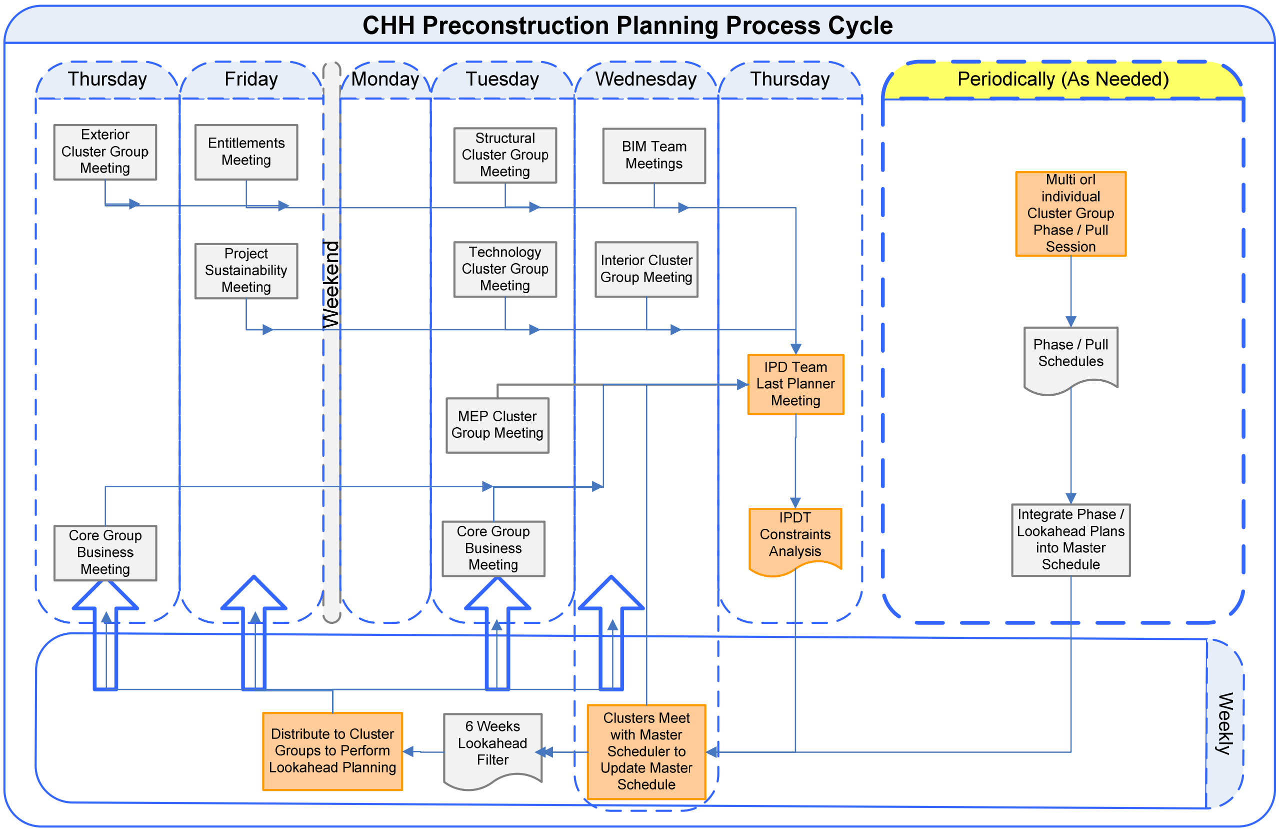

Figure 3: Information Flow Model for Planning Processes at CHH (Modified from The Last Planner Handbook at CHH, 2009)

CONCLUSIONS AND FUTURE RESEARCH

Collaborative planning and continuous re-planning are major constituents of the planning process at CHH during design where iterations are ubiquitous, tasks are complex and interdependent, and constraints need to be removed in time for task execution. Accordingly, cluster and intra-cluster team planning is vital to the success of this process as they provide means for sharing incomplete information, identifying constraints, removing constraints as a team, monitoring performance, and learning from plan failures. Continuous re-planning plays a central role in lookahead planning and weekly work planning accounting for uncertainties in design tasks including: task duration, task sequence, task scope, task prerequisites, and constraints.

Despite the various challenges emanating from the novelty of the last planner system to designers at CHH, the integrated project delivery team took long strides in transitioning to the new planning process. This was evident in the "Cathedral Hill Pulse Report" which involved results and feedback from team members on a survey investigating the team's performance in various management areas (CHPR 2008). I can conclude from the collected evidence that: (1) architects and designers became more comfortable planning their weekly work and utilizing pull sessions, (2) LPS helped boost communication within a cluster and among clusters, (3) learning from failures did not take full shape within LPS although but was counterbalanced with the use of the A3-problem-solving process that involved analysis of past actions and suggestions for improvement (Shook 2008), (4) training on LPS contributed to rapid deployment of the planning process, and (5) the role of the owner and the core group was a key component in supporting process implementation.

At the time of writing this paper, not enough data was available to compare performance metrics before and after implementing the new planning process. Such comparison would help highlight "improved" areas versus "to improve" areas. It will enrich results from this case study and serve as basis for future improvements. We hope to present these results in future research publications.

Compared to the informal fashion in which construction companies practice production planning and control (Kemmer et al. (2007), this case study highlights the importance of standardized production planning and control practices as proxies for performance measurement and process improvement.

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