IMPROVING CONSTRUCTION WORK FLOW – THE CONNECTIVE ROLE OF LOOKAHEAD PLANNING

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ABSTRACT

Lookahead planning is a fundamental process in the Last Planner^{TM} system of production control, which encompasses four tiers of planning processes: master scheduling, phase scheduling, lookahead planning, and commitment planning. Lookahead planning means not just viewing near-term tasks from the master or phase schedule and possibly detailing them, but it is a process to make tasks ready and create a workable backlog of tasks. The purpose of this paper is to report on research dedicated to improving the Last Planner^{TM} system in general and the lookahead process in particular. The paper describes the role of lookahead planning as a connector between long term planning and commitment planning. Research is presented on two projects in North America combined with preliminary results from a survey investigating the Last Planner^{TM} implementation and the performance of the lookahead process. The data collected was employed to evaluate the current practice, suggest hypotheses for improvement, and introduce experiments to test these hypotheses. The study findings indicate an inadequate performance of the lookahead process mainly due to the lack of instructions such as Last Planner^{TM} implementation guidelines or related standardized integrative practices. The paper suggests guidelines and reports on research concerned with producing, testing, and improving the required instructions.

KEY WORDS

Lookahead planning, production control, lean construction, Last Planner^{TM} system, rationalizing production.

INTRODUCTION

Uncertainty and variability are endemic to all production systems including those in the construction industry (e.g., Crichton 1966, Hamzeh et al. 2007).

Establishing a consistent work flow, reducing uncertainty, and rationalizing production has been researched by many scholars and industry practitioners in

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the last 40 years. Thompson's (1967) study on organizational and technical rationality highlights the importance of rationalizing production or what he calls "rationalizing technical core activities" of an organization. He argues that, under norms of rationality, organizations try various methods to maintain consistency in production flow and shield production from uncertainty in the environment. The first technique is buffering to cater for variations on both the input and output sides. Figure 1 shows an example of applying buffers to production inputs at a construction site. Inputs typically needed for successful execution of tasks include: information, prerequisite work, human resources, space, material, equipment, external conditions, and funds (Koskela 2000, Ballard et al. 2003). To make sure that these inputs are available and hence planned work load is actually realized, actions can be taken ahead of scheduled start dates to make tasks ready thus utilizing a time buffer. Inventory buffers are also commonly used to assure realization of work load. Capacity can be buffered by reserving the use of overtime and by maintaining labor capacity in excess of the average needed.

While buffering may not cater for all variations, organizations try to smooth the supply and demand side by impacting the outside environment as well as internal operations. An example is leveling the work load or *heijunka* as advocated in the Toyota Production System (Liker 2004). To attend to the remaining variations, organizations employ various forecasting methods to anticipate and adapt to changes in their environment. When all else fails, organizations restrict the allocation of resources creating what is called production rationing (Thompson 1967). All these techniques (buffering, smoothing, anticipating, and rationing) can be used in production planning and control systems.

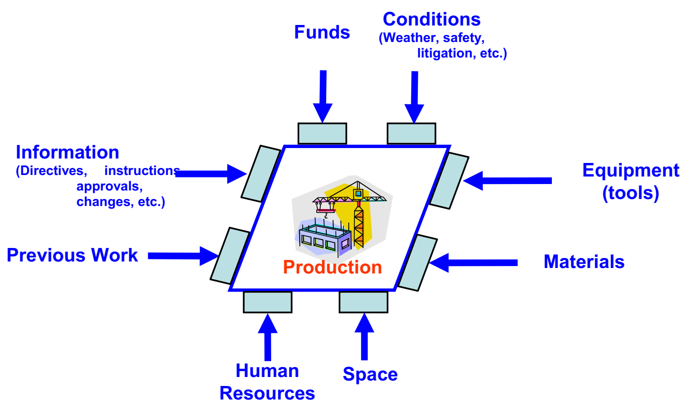

Figure 1: Shielding production from the effects of uncertainty in inputs (adopted from Koskela 2000, Ballard et al. 2003, and Bertelsen et al. 2007)

One such production planning and control system is the Last Planner™ system, which has been successfully implemented on construction projects

(Ballard and Howell 2004) to increase the reliability of planning, improve production performance, and create a predictable/smooth workflow in the face of high uncertainty in design and construction operations. Despite the advantages of this system, the current practice on many construction projects shows a gap between long-term planning (master and phase schedules) and short-term planning (lookahead plan and commitment/weekly work plan) reducing the ability of the planning system to establish foresight. The wider this gap is, the farther the weekly plan is from executing activities that count towards achieving milestones and, consequently, the lower is the ability of percent plan complete (PPC) to explain the degree of project progress.

This paper presents an assessment of an implementation of the Last Planner™ system, highlights some of the gaps in running the planning system, emphasizes the role of lookahead planning as a prime driver to the success of weekly work planning, and suggests guidelines for improving the lookahead planning process. It reports results of research conducted by the Project Production Systems Laboratory (P^2SL) at University of California-Berkeley on improving workflow in the construction industry and the advancement of the Last Planner™ system.

THE LAST PLANNER™ SYSTEM

The Last Planner™ system was developed by Glenn Ballard and Greg Howell as a production planning and control system to assist in developing foresight, smoothing variations in construction work flow, and reducing uncertainty in construction operations. Percent plan complete (PPC) measures the percentage of tasks completed relative to those planned. It thus helps measure the predictability of future work load and initiates preparations to perform work as planned. Previous research has found that implementing the Last Planner™ system has a direct impact on workflow variation and labor productivity. Secondary impacts include possibly improvements in work safety and quality (Ballard and Howell 1998, Ballard et al. 2007, Liu and Ballard 2008).

Figure 2 shows the Last Planner™ system comprising four levels of planning processes with different chronological spans: master scheduling, phase scheduling, lookahead planning, and commitment planning.

1- The *master schedule* is the output of front-end planning describing work to be carried out over the entire duration of a project. It involves project-level activities mostly in relation to contract documents. It identifies major milestone dates and incorporates critical path method (CPM) logic to determine overall project duration (Tommelein and Ballard 1997). CPM logic can be represented in different forms such as Gantt, PERT (Program Evaluation Review Technique), or line of balance.

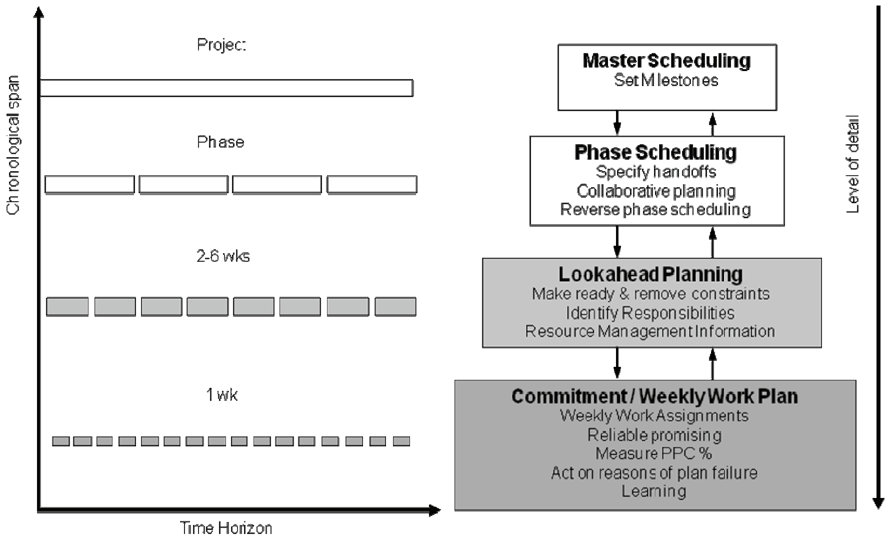

Figure 2: Planning stages/levels in the Last Planner ™ system for production planning and control (adopted from Ballard 2000).

2- *Phase scheduling* generates a detailed schedule covering each project phase such as foundations, structural frame, and finishing. In a collaborative planning setup, the phase schedule (or pull schedule as named in the industry) employs reverse phase scheduling (scheduling activities back from project milestones) and identifies handoffs between the various specialty organizations to find the best way to meet milestones stated in the master schedule (Ballard and Howell 2004).

3- *Lookahead planning* signifies the first step of production planning with a time frame usually spanning between two to six weeks (supporting the ability to pull). At this stage, activities are broken down into the level of processes/operations, constraints are identified, responsibilities are assigned, and assignments are made ready (Ballard 1997).

4- *Commitment planning* represents the most detailed plan in the system showing interdependence between the work of various specialist organizations. It directly drives the production process. Plan reliability at this level is promoted by making only quality assignments and reliable promises so that the production unit will be shielded from upstream uncertainty. The work assignment is a detailed measurable commitment of completion. At the end of each plan period, assignments are reviewed for completeness in order to measure the reliability of the planning and production system. Analyzing reasons for plan failures and acting on these reasons is the basis of learning (Ballard 2000).

The Last Planner™ system can be related to deliberative and situated action models as advocated by Bolivar (2007). However, the Last Planner™ system combines aspects of both worlds. On one hand, deliberative planning 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, the lookahead and weekly work plans are closer to the situated planning model where plans take into account changes in the environment affecting inputs and outputs of construction activities.

METHODOLOGY

This paper summarizes exploratory research conducted to study the impact of the Last Planner™ system on improving construction workflow and increasing the reliability of planning. Research involves both a case study research method (Yin 2003) and preliminary results from a survey covering the Last Planner™ implementation.

The case studies involve two health care projects in the United States (US): a hospital renovation and a new hospital construction. At the time this paper was written, the first project was in the construction phase while the second project was still in preconstruction. Both projects employed the Last Planner™ system for production control. The research process comprised the following steps: evaluating the current practice, developing guidelines for improvements, and testing these guidelines.

Data was collected by conducting short interviews, attending weekly or special planning meetings, and performing exercises to assess the performance of the lookahead process and weekly work planning.

In addition to case study research, an industry-wide survey was conducted with help of the Lean Construction Institute LCI among Last Planner™ system users inside and outside the US. The survey aims at assessing the implementation of the system, informing research on obstacles faced in the current practice, and providing feedback required in shaping the formation of guidelines for improvement.

The survey explores several issues: performance of the planning process during the four stages of the Last Planner™ system, organizational setup of the lookahead process, planning/scheduling methods used in developing activities on the lookahead plan, software programs used to develop schedules at the various levels of the planning system, the process of identifying and removing constraints, the compatibility between lookahead plan and weekly work plan, and methods employed for acting on reasons for variance from plan.

This research reflects the planning methods of organizations adopting the lean construction approach and accordingly do not speak for the whole construction industry.

CONCERNS WITH CURRENT PRACTICE

Research findings from case studies and preliminary results of the survey raise concerns regarding the performance of the planning system. The results show inadequate implementation of planning processes especially at the lookahead level. Concerns include:

- Deficiencies in the application of standardized planning processes required to clearly explain procedures for crucial planning processes such as schedule development, feedback, and updates for all four levels of the planning system but especially lookahead planning.

- Some projects do not develop a phase schedule or do not develop a phase schedule for all project phases; thus missing the opportunity to identify handoffs and perform collaborative planning.
- Lookahead plans are mainly developed by presenting a near term view of activities shown on the master schedule. These activities tend to be generic, span a long time, and do not cater for specificities of short term activities taking place in a window of two to six weeks. This short circuits the planning of operations, coordination of activities, and identification of constraints for removal that should take place in lookahead planning, thus reducing the planner's ability to make activities ready at the lookahead level.
- Projects that are not employing collaboratively developed phase schedules use lookahead plans as near term view of tasks on a master schedule. The resulting lookahead plans do not necessarily incorporate input from project stakeholders such as owners, designers, contractors, subcontractors, suppliers, regulatory authorities, and user groups. Moreover, they may not account for inputs from last planners who are directly involved in production. This undermines the quality of planning and the ability to establish foresight.
- Different scheduling software packages are used to prepare long term and short term schedules such as Primavera for lookahead planning and Excel for commitment plans. This creates an epistemic bias when developing commitment/weekly work plans due to poor linkage between production schedules and project progress milestones.
- While some constraints are identified and removed at the commitment/weekly work plan level, other constraints having a lead time beyond the weekly work plan window are not identified and removed in time due to poor foresight capacity of the lookahead plan.
- Some projects do not analyze the reasons behind plan variance at the commitment/weekly work plan level. This leaves the plan, do, check, and act cycle (PDCA) open since the root causes are not discovered. Accordingly, no action is taken to prevent the variances from taking place again.
- Results show poor development and linking between the master schedule, phase schedule, lookahead plan, and commitment/weekly work plan. Performance at the commitment level and PPC become loosely linked to overall project progress. This reduces the power of the Last PlannerTM system to forecast and increases the team's reactive approach to performing work activities especially under high uncertainty conditions.

INSTRUCTIONS TO BE TESTED

Addressing the aforementioned concerns is complex. To what extent are currently published instructions sufficient, but not being followed; and if not, why not? To what extent are currently published instructions insufficient? If so, what instructions are needed and how best to test them?

On one hand, instructions for commitment/weekly work planning appear to be well established and research results show a comparably better performance at the commitment/weekly work plan level in terms of procedures and organizational setup. On the other hand, the function and preliminary guidelines for the lookahead planning process have already been laid out by Ballard (1997), Tommelein and Ballard (1997), Ballard (2000), Ballard et al. (2003), Ballard and Howell (2004), and Kremmer et al. (2007). However, further work is required to develop detailed procedures for running the overall planning process and testing these procedures experimentally. The following guidelines extend those in the literature with new refinements derived from research findings and issues endemic to current practice. These guidelines are grouped under procedural, organizational, and technical aspects.

PROCEDURAL ASPECTS

Lookahead planning is instrumental in shaping the sequence and rate of work flow, linking long and short term planning, shielding production by removing constraints, sizing work flow to match capacity and constraints, producing a backlog of workable activities, and developing short term plans of how work is performed (Ballard 2000, Ballard et al. 2003). A lookahead plan means not just viewing near-term tasks from the master or phase schedule and possibly detailing them, but it is a process to make tasks ready and create a workable backlog of tasks by screening and pulling. Screening entails subjecting tasks to constraint analysis and culling out those activities missing prerequisites such as information, material, previous work, manpower, and space. Pulling involves making activities ready by removing constraints to ensure the availability of prerequisites as per actual site demand.

Lookahead plans typically span two to six or more weeks of planned activities. Figure 3 depicts a six week lookahead process showing a mechanism for breaking down activities by week and the progress of the lookahead plan as it evolves from long to short term activities. When developing a lookahead plan, the following guidelines should be kept in mind to reinforce compatibility between the lookahead plan and the weekly work plan:

1- Activities enter the six week lookahead plan from the phase schedule. Gross constraints analysis is performed at this stage. Gross constraints are those that apply to phase-level tasks; primarily materials and information. Having a phase schedule is helpful in identifying handoffs and gross constraints early on. Constraints analysis leads to developing a plan for constraint removal necessary to make activities ready in time for execution. Removing constraints such as those related to availability of prerequisites such as material, information, and previous work can take place anywhere within the six weeks. However, it is desired to remove constraints to the extent possible two weeks prior to activity execution.

2- When scheduled tasks enter the fourth week of the lookahead window, i.e., they are 4 weeks ahead of scheduled start, the project team delays those tasks they are not confident can be made ready in time.

3- Activity break down also starts in the fourth lookahead week. Tasks are divided into smaller time chunks, moving from phases into processes, operations, and steps. As shown in Figure 3, "Boulders" are phases such as 'superstructure,' "Rocks" are processes such as 'build walls,' and "Pebbles" are operations such as 'lay formwork.' "Dust" represents the steps that make up operations, but these are not shown in coordinating work plans between specialist work teams, but rather managed by last planners to achieve coordination within their work teams such as 'acquire steel walers.' Activity breakdown goes hand in hand with defining work to be done, sequencing work in the most optimal way, coordinating activities among project stakeholders, loading with resources, sizing to match load to capacity, and analysis for soundness. The latter includes confirming prerequisite inputs are ready (inputs such as previous work, information, material, labor, and space). Figure 3 uses boulders, rocks, pebbles, and dust to show the level of detail in planning as activities move closer to the weekly work plan.

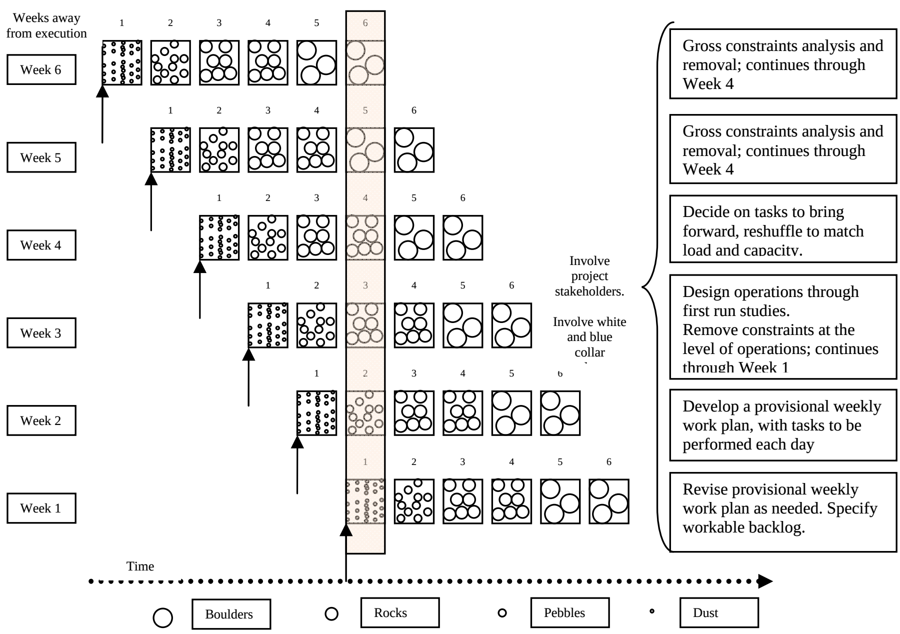

Figure 3: Example six weeks lookahead planning process

4- While designing operations and developing detailed plans for work execution, first run studies should be performed for new operations to evaluate the devised plan, launch refinements, and establish standardized work.

5- Lookahead plan activities are broken down and detailed as they move closer to execution. Accordingly, when activities are one week away from execution, they will match the detail required for production at the weekly level so they can be moved directly to the weekly work plan.

Two measurements are proposed to monitor the performance of the lookahead process: (i) *Tasks Anticipated* (TA) to measure the performance of lookahead planning in anticipating tasks that need to be made ready, and (ii) *Tasks Made Ready* (TMR) to measure the performance of lookahead planning in making scheduled tasks ready once they appear in the lookahead window.

Figure 4 shows planned and anticipated tasks for: (a) a lookahead plan two weeks away from execution, (b) a lookahead plan one week away from execution, (c) a commitment/weekly work plan, and (d) an executed weekly work plan. Dividing the number of activities completed (8) by those planned (10) (ignoring completed back log activities) gives an 8/10 = 80% PPC. Comparison of the lookahead plan one week away (LA 1wk) from execution and the weekly work plan shows that out of the 9 tasks showing on the lookahead plan only 5 made their way to the weekly work plan. These 5 were successfully anticipated at (LA 1wk) which results in 5/9 = 55.5% TA. However, 4 of the 9 planned activities showing on the lookahead plan were made ready and eventually got executed, so this results in 4/9 = 44.4% TMR. The same calculation can be performed to measure the performance of the lookahead plan two weeks away (LA 2wks).

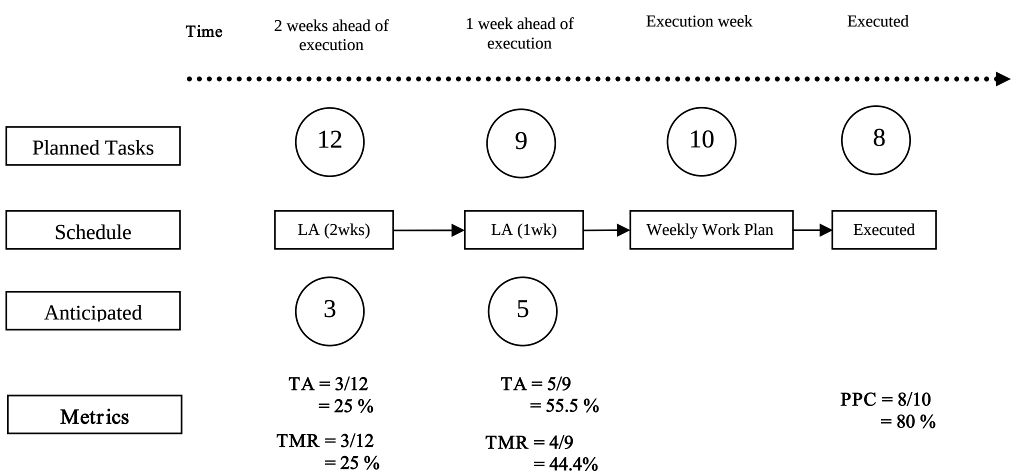

Figure 4: Measuring tasks anticipated, task made ready, and percent plan complete

While PPC has been considered the main performance metric at the commitment/weekly work plan level, TA and TMR represent performance metrics at the lookahead process level. They indicate the production team's ability to plan well ahead of execution, which translates into foresight in anticipating tasks and identifying constraints, as measured by TA. However, establishing foresight is one part of the effort. It should be followed by a proactive removal of constraints and prioritizing tasks for execution, as captured by measuring TMR. One premise claimed here is that increasing TA and TMR result in an increase in PPC. However, this claim needs to be tested in practice.

ORGANIZATIONAL ASPECTS

A consequence of the lack of instructions and established practices for developing, monitoring, and updating lookahead plan, the roles and responsibilities of each specialist organization are not clearly laid out. While it is imperative that schedule development is a collaborative effort among all project stakeholders, clear guidelines and standardized processes can help make it happen.

As shown in figure 3, the guidelines suggested at this stage emphasize engaging all stakeholders such as owners, contractors, designers, subcontractors, suppliers, regulatory agencies, and user groups in developing the lookahead plan and disseminating this information to all for monitoring and feedback. Another organizational guideline is engaging managers, engineers, superintendents, and foremen in schedule development to establish a sense of ownership by both rank and file employees.

It is important to develop a system for organizing and disseminating schedule information, defining roles and responsibilities, and standardizing practices among users. Preliminary work on establishing such a system was presented by Chua et al. (1999) who proposed a tool to share and disseminate schedules among project participants and stakeholders.

TECHNICAL ASPECTS

Scheduling software that can be jointly used by managers, schedulers, and last planners during the four stages of the Last Planner^{TM} system is recommended. This can close the gaps in logic, sequence, definition, etc., created by marrying schedules produced using multiple software packages.

Moreover, employing software packages capable of accommodating feedback and schedule updates from all stakeholders and last planners reduces double data entry and helps reinforce the collaborative planning behavior supported by the application of the Last Planner^{TM} system.

CONCLUSIONS AND RECOMMENDATIONS

Research findings underline the deficiency in current planning systems mainly due to the lack of instructions and lack of application of standardized planning processes that clearly explain planning processes such as schedule development, feedback, responsibilities, and updates. These results match the finding of Kemmer et al. (2007) who draw attention to the informal fashion in which construction companies practice production planning and control.

Results suggest that when commitment/weekly work plans are not properly linked to long term plans, percent plan complete (PPC) becomes loosely linked to project progress. Accordingly, last planners become more reactive and the planning system loses its ability to develop foresight. However, the guidelines proposed in this paper are expected to improve the performance of the lookahead process by increasing the linkage between the commitment/weekly work plan and long term plans. Measuring TA and TMR is expected to gauge the performance of the lookahead process and enable statistical analysis of the impact of TA and TMR on PPC.

The presented guidelines will be experimentally tested in industry. Results will be used to refine the current guidelines and establish a standardized practice for the lookahead planning process specifically, and the Last Planner™ system generally. Moreover, testing the effects of increasing TA and TMR on PPC will also be considered in this experiment. Results of this experiment will be shared in future publications.

Although this research highlights many aspects of planning during preconstruction, further research is required to describe, analyze, and understand planning/scheduling issues pertaining to the uncertain environment of design.

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