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Rethinking Lookahead Planning to Optimize Construction Workflow

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Abstract

Research Question: How to improve lookahead planning practices in the construction industry to increase the reliability of production planning?

Purpose: To assess the performance of lookahead planning, advise a standardized practice to support a strong linkage between Lookahead planning and activity execution, and improve the reliability of production planning.

Research Design/Method: This study employs case study analysis, industry interviews, and an industry survey to assess the current implementation of lookahead planning on construction projects in North America, South America, and Europe.

Findings: The study findings indicate the existence of non-compliance with Last Planner® System rules, inadequate lookahead planning and standardized practices, sluggish identification and removal of constraints, and absence of analysis for plan failures.

Limitations: The authors' active role on the projects used as case studies may constitute a limitation to the research methods and tools used. The industry survey may have not covered all companies applying the Last Planner System. The suggested framework should be custom tailored to different projects to cater for size, culture, etc.

Implications: This research provides a framework for applying the Last Planner System rules during lookahead planning. It aims at increasing the success of the making activities ready, designing operations, and ultimately improving PPC.

Value for practitioners: The study presents to industry practitioners applying the Last Planner System a standardized framework for implementing lookahead planning on construction projects. The paper also highlights the use of two metrics to assess the performance of lookahead planning at a given point in time and to monitor performance over a period of time or between projects.

Keywords: Lookahead planning, production planning, production control, lean construction, the Last Planner System, construction planning.

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Introduction

Architecture, Engineering, and Construction (AEC) processes are plagued with problems associated with variations that undermine project performance and disrupt workflow leading to detrimental impacts on project's duration, cost, and quality (Hamzeh et al. 2007, Hopp and Spearman 2008, Salem et al. 2006, and Crichton 1966). Organizations use a number of different methods to maintain consistency in production flow and to shield production from variations in internal business processes as well as the external environment. Thompson (1967) highlighted some of these methods including:

- Forecasting
- Buffering
- Smoothing

Various forecasting methods are used to anticipate variations in internal processes and in inputs to production. However, forecasts cannot cater for all variations and have many limitations: the more detailed a forecast is the more off it will be, the farther a forecast looks into the future the less accurate it becomes, and forecasts are always wrong (Nahmias 2009).

Buffering is used to mitigate process variations on both the input and output sides. Inputs typically needed for successful execution of tasks include: information, prerequisite work, human resources, space, material, equipment, external conditions, and funds (Ballard & Howell 1994, Koskela 2000).

Buffers can take on one of three main forms: time, inventory and capacity. Time buffers allocate slack to an activity, inventory buffers utilize extra stock to account for supply variations, and capacity buffers reserve extra capacity such as using overtime or maintaining machinery used only when needed to accommodate surges in load.

Smoothing variations in supply and demand is another method that organizations apply since buffering may not be enough to cater for all variations, is costly to apply, and may lead to complacency. An example of smoothing demand is leveling the work load or *heijunka* as advocated in the Toyota Production System (Liker 2004).

Although variation undermines project performance, production systems can be designed to reduce them and to manage residuals utilizing a combination of the above mentioned methods.

A production system can be defined as a collection of people and resources (e.g., machinery, equipment, information) arranged to design and make a product ("goods" or "services") of value to customers (Ballard et al. 2007). A cornerstone of a production system is production management such as 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 predictable workflow in design and construction operations.

On any project, the planning process can be plagued by various problems. Planning involves forecasts that can be inaccurate the further they project into the future (Nahmias

2009). It is hard to execute work schedules when Planners push plans to frontline specialists without involving them in plan development. Short-term work plans developed on the basis of wishful thinking and in absence of reliable promises from trade experts are more likely to fall short during execution. And if causes of plan failures are not identified and dealt with in a timely fashion, further failures are bound to happen (Hamzeh 2009). Moreover, reliable planning depends on effective constraint analysis and removal. Constraints are those prerequisites required to be present before an activity can start (e.g., previous work, information, labor, material, equipment, tools, space, weather, etc.). Managing constraints can help optimize work plans by identifying resource conflicts and resolving them prior to work start. Without constraint removal, it is hard to manage and reduce work flow uncertainties that often cause process variations (Chua et al. 2003).

Taking into account the challenges mentioned above, the Last Planner System advocates the following steps in project planning:

- Plan in greater detail as you get closer to performing the work (Cohn 2006)
- Develop the work plan with those who are going to perform the work
- Identify and remove work constraints ahead of time as a team to make work ready and increase reliability of work plans
- Make reliable promises and drive work execution based on coordination and active negotiation with project participants
- Learn from plan failures by finding root causes and taking preventive actions (Ballard, et al. 2009)

Despite the advantages of this system (Alarcón and Cruz 1997, Gonzalez et al. 2008), the current practice on many construction projects shows a poor implementation of lookahead planning resulting in a wide gap between long-term planning (master and phase schedules) and short-term planning (commitment/weekly work plans) reducing the reliability of the planning system and the ability to establish foresight.

This paper presents an assessment of lookahead planning implementation as one process in the Last Planner System, highlights some inadequacies in operating the planning system, emphasizes the role of lookahead planning as a prime driver to the success of weekly work planning, and suggests guidelines for performing lookahead planning pertaining to activity breakdown, operation design, and constraint analysis.

The Last Planner System

The Last Planner System as developed by Glenn Ballard and Greg Howell is a system for production planning and control used to assist in smoothing variations in construction work flow, developing planning foresight, and reducing uncertainty in construction operations. The system originally tackled variations in workflow at the weekly work plan level but soon expanded to cover the full planning and schedule development process from master scheduling to phase scheduling through lookahead planning to reach weekly work planning.

Percent Plan Complete (PPC) is a metric used to track the performance of reliable promising at the weekly work plan level by measuring the percentage of tasks completed relative to those planned. It thus helps assess the reliability of work plans and initiates preparations to perform work as planned. PPC is not a direct measure of project progress, but rather a measure of the extent to which promises are kept, and hence the extent to which future work load may be predictable. Previous research has found a correlation between PPC and labor productivity (Liu and Ballard 2008). Possible secondary impacts of PPC on improving work safety and quality require further research (Ballard and Howell 1998, Ballard et al. 2007). Despite the advantages of the LPS, research has shown that many organizations face significant hurdles when implementing the system (Ballard et al. 2007; Hamzeh, 2009; Viana et al. 2010). Hamzeh (2011) presented a framework for successful implementation of the Last Planner System on construction projects.

However, when the entire Last Planner System (master scheduling, phase scheduling, lookahead planning, and weekly work planning) is executed and updated as designed, PPC should be an indicator of project progress; i.e., PPC and progress should vary with each other. This claim can be expressed as a complex hypothesis; namely:

> *H1: If lookahead tasks are drawn from a phase schedule structured to achieve the project end date and intermediate milestones, and if lookahead planning makes ready what SHOULD be done, and if weekly work plans are formed from what CAN be done selected from what SHOULD be done in the order of criticality without gaming the system, PPC will vary with project progress.*

If we accept this hypothesis as an assumption, it follows that if PPC does not vary with project progress, there is a broken link somewhere in the hypothesized chain.

Figure 1 shows the Last Planner System where activities are broken down from phases (boulders) to processes (rocks) then to operations (pebbles) across four planning processes with different chronological spans: master scheduling, phase scheduling, lookahead planning, and weekly work planning.

Master scheduling is a front-end planning process that produces a schedule describing work to be carried out over the entire duration of a project. It involves project-level activities and identifies major milestone dates mostly in relation to contract documents and the owner's value proposition (Tommelein and Ballard 1997).

Phase scheduling generates a schedule covering each project phase such as foundations, structural frame, or finishing. In a collaborative planning setup the project team: (1) defines a project phase or milestone, (2) breaks it down into constituent activities, and (3) schedules activities backward from the milestone. After incorporating input from different project parties and identifying hand-offs between specialists, the team performs reverse phase scheduling back from important phase milestones (Hamzeh 2009, Ballard and Howell 2004).

Lookahead planning is the first step in production control (executing schedules) and usually covers a six week time frame. Lookahead time periods vary with the type of work being performed and the context. (For example, in conceptual design, tasks cannot be foreseen at a detailed level very far in advance because of the phenomenon of emergence. In plant shutdowns, the lookahead period extends to the end of the shutdown. In this research, the focus is on normal construction projects, and on those 4 to 6 week time frames are commonly used in lookahead planning). At this stage, activities are broken down into the level of production processes/operations, constraints are identified, operations are designed, and assignments are made ready (Ballard 1997, Hamzeh 2009).

Weekly work planning (WWP) also known as commitment planning represents the most detailed plan in the system, shows interdependence between the works of various specialist organizations, and directly drives the production process. Plan reliability at this level is promoted by making quality assignments and reliable promises so that the production unit will be shielded from uncertainty in upstream operations. The work assignment is a detailed measurable commitment of completion. At the end of each plan period, assignments are reviewed to assess whether they are complete or not, thus measuring the reliability of the planning. For incomplete assignments, analyzing the reasons for plan failures and acting on these reasons is the basis of learning and continuous improvement (Ballard 2000).

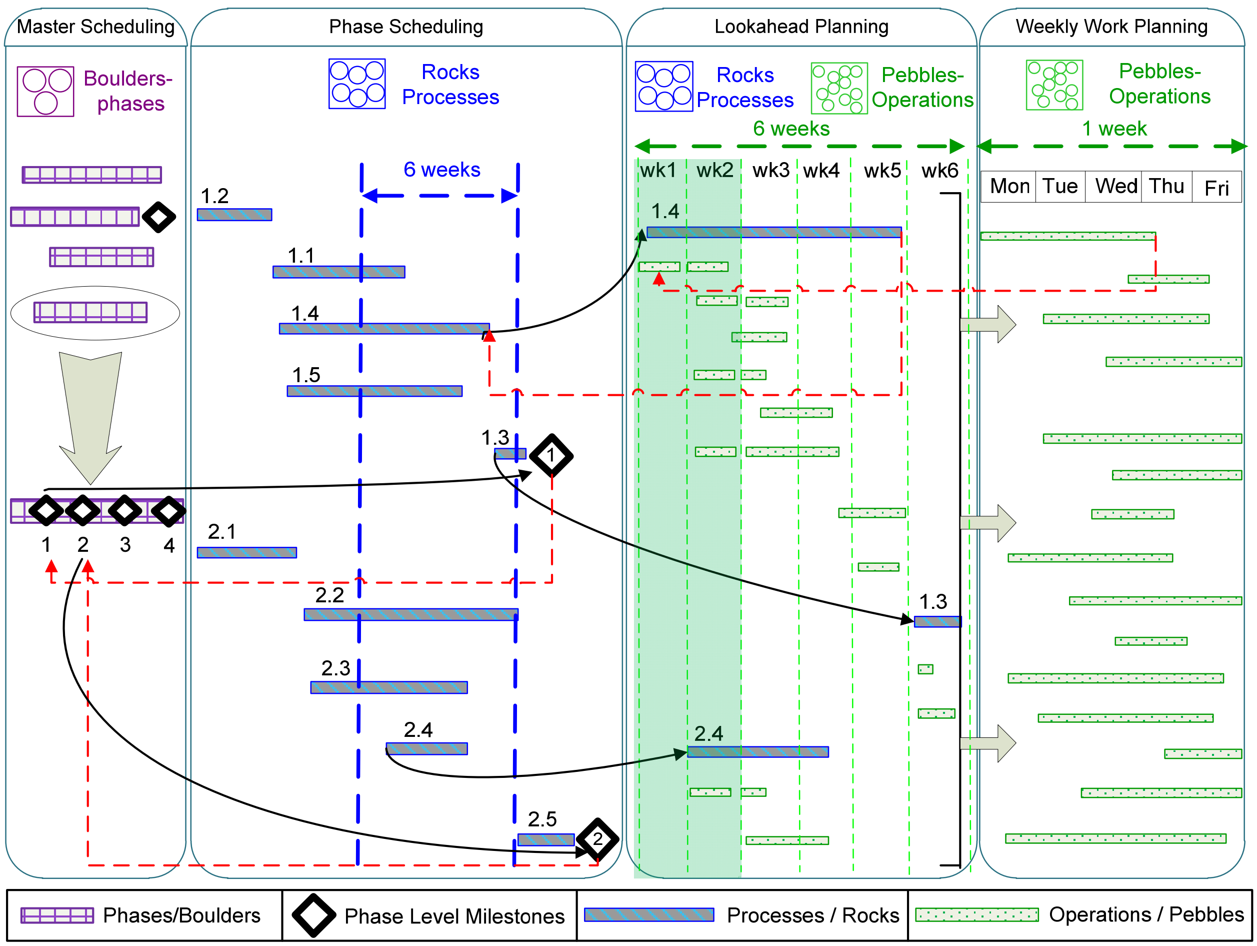

Figure 1: Planning processes in the Last Planner System.

The Last Planner System relates to deliberative and situated action planning as described by Senior (2007) combining aspects of both worlds. On one hand, deliberative planning takes place at the master and phase scheduling level where a premeditated course of action is specified 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.

However, a question remains unanswered: how can the AEC industry advance the implementation of the lookahead planning within the Last Planner System to improve construction workflow and the reliability of planning?

Accordingly, this paper reports an assessment of the current implementation of the Last Planner System in construction, presents analytical data, highlights concerns with the current practice, and lays out recommended procedures to perform lookahead planning aiming at producing more reliable production plans.

Methodology

This paper summarizes research conducted to study the role of lookahead planning within the Last Planner System in improving construction workflow and increasing the reliability of planning. Research involves results from two construction projects and preliminary results from a survey addressing Last Planner implementation (Hamzeh 2009).

Case study research was the methodology adopted in this study because:

1. It is appropriate 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 utilizes multiple sources of evidence in a natural setting that encompasses temporal and contextual facets of the variables monitored.
4. It uncovers the dynamics of events explaining the phenomenon under study.
5. It provides qualitative understanding when arriving at conclusions and analyzing results (Meredith 1998, Stuart et al. 2002, Yin 2003).

The case studies involve two health care projects in the United States. Both projects employed the Last Planner System for production control investing heavily in employee training and in different aspects of lean construction. The owner on both projects is a strong advocate of lean and integrated project delivery systems. The authors also conducted some interviews with industry practitioners who worked on these projects.

The first author spent fourteen months on project one working for ten months as a researcher and four months as an intern. While he was more of an observer in the researcher position, he had more input into the process while working as an intern helping the development of a planning process. The first author also spent around eight months on project two helping in the implementation of the Last Planner System and applying a new software application to manage the planning process.

Prior to case study research, an industry-wide survey was conducted among Last Planner System industry users in the US, south America, and Europe. The survey addressed engineers and managers working for owners, architects/engineers, and contractors. The companies were identified with help of the Lean Construction Institute (LCI). The survey aimed 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 research process follows an inductive reasoning scheme adjusted to the specific situation. Accordingly the research process comprised multiple steps of evaluating and assessing the current practice, developing guidelines for improvements, and testing these suggested guidelines. In collecting data (e.g., PPC historical project data, master schedule data) several methods were employed such as: conducting short interviews, attending weekly or pull/phase scheduling sessions, attending value stream planning sessions, and performing exercises to assess the performance of the lookahead process and weekly work planning.

Case Study One

The first case study is a 555-bed hospital and medical campus in San Francisco, California. The $1.7 billion project comprises a 16-story hospital including two below-grade floors. This is a project to study because of:

- implementing integrated project delivery (IPD) and integrated form of agreement (IFOA)
- engaging project partners who are interested in experimenting with lean practices
- applying Last Planner System for production planning and control,
- utilizing target value design (TVD) to steer design towards meeting the owner's value proposition
- using building information modeling (BIM) extensively

As explained above, we assume for the moment that if the Last Planner System is implemented correctly, PPC and project progress should vary together. To determine if they in fact do vary together, and hence if implementation is correct, an investigation was performed to compare slips or gains on the master schedule with each update to weekly work planning performance expressed in percent plan complete (PPC). This investigation comprised an in-depth study of the master schedule built in Primavera P6 scheduling software including:

- Monitoring project milestones with each update.
- Tracking changes to the schedule in terms of rescheduling, adding activities, adding detail into current activities, changing sequence/logic, altering durations, and adding modules suggested during phase planning sessions.
- Analyzing the incremental slip or gain on schedule with each update.

Assessing the weekly work planning performance was performed by monitoring PPC with each weekly update. To adequately compare weekly PPC and incremental schedule changes on the master schedule, an aggregate PPC figure was calculated over 3 or 4 weeks, which is the average cycle for master schedule updates.

Figure 2 shows the relationship between percent plan complete (PPC) and the incremental schedule difference in days (+ is schedule delay and – is schedule gain). If system implementation was correct (drawing tasks into the weekly work plan that are critical without gaming the system), the higher the PPC the lower the schedule slip should be. However, results show a weak correlation of 0.28 and a covariance of 1.01 between PPC and negative incremental schedule difference. Therefore, a clear relationship between weekly performance and overall schedule performance was not found.

Moreover, the highlighted area in Figure 2 shows an increase in project delays (+ increment) for a higher PPC when more work was actually completed on the weekly schedule[3]. These results suggest that in Case 1 project, there is no evidence that variation in the incremental schedule difference can be explained by PPC. This may indicate a poor linkage between weekly work plans and the master schedule.

Since earned value analysis is used to measure progress it may sometimes tempt teams to work out of sequence to maximize progress gains in a certain period. While this may have an impact on the relationship between PPC and incremental schedule difference, it is still in violation of the caveats stipulated in hypothesis H1 and a result of an incorrect development of the master schedule into a lookahead plan and an incorrect development of the lookahead plan into a weekly work plan. That is why both working out of sequence and gaming the system are indications of poor implementation of the LPS and a poor linkage between weekly work plans and the master schedule.

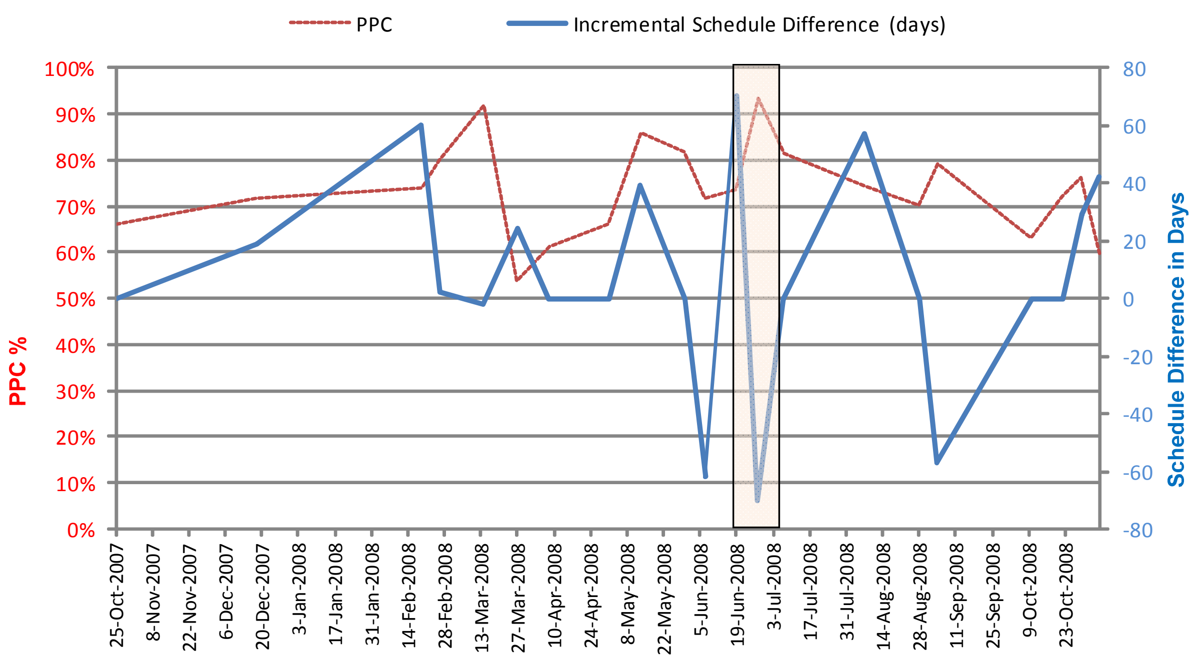

Figure 2: The relationship between Percent Plan Complete (PPC) and incremental schedule difference for case study 1

Case Study Two

The second case study project involved rehabilitation of 23 buildings, new construction of 14 buildings, and landscape works for Fort Baker Retreat Group LLC at Fort Baker, Sausalito, California (Quakenbush 2008). The project budget was $103 million. This project

[3] While the two negative increments may be due to optimistic updating at the user level, the positive and negative increments do not correlate with PPC figures.

was chosen because the schedule was broken down into separate phases that were monitored and recorded.

This study focuses on the production management practices performed on the rehabilitation section of the project where the general contractor (GC) used the Last Planner System to manage production. The GC developed the master schedule for the project using phase scheduling sessions in collaboration with trade contractors and subcontractors. The team focused on the project handover and everything in between project start and project handover was decided using pull sessions. The GC continuously incorporated results from these sessions into the master schedule that was built in Microsoft Project and updated on a weekly basis. This schedule was developed to allow for a flow of construction trades from one building to another. The project team used the Last Planner System to develop and manage weekly work planning based on the master schedule. Although the team did not apply lookahead planning, they conducted weekly meetings for last planners who developed the next week's plan, coordinated their work, and used PPC to monitor the performance of production planning (Hofmann 2008).

To compare the performance of master scheduling and weekly work planning, the incremental schedule difference (gain or slip) for each master schedule update measured against the earlier update was compared to the percentage of tasks performed on the weekly work plan represented by PPC. Figure 3 plots the incremental schedule difference measured with each update against the corresponding PPC covering the period of fifteen months for one specific building on the project.

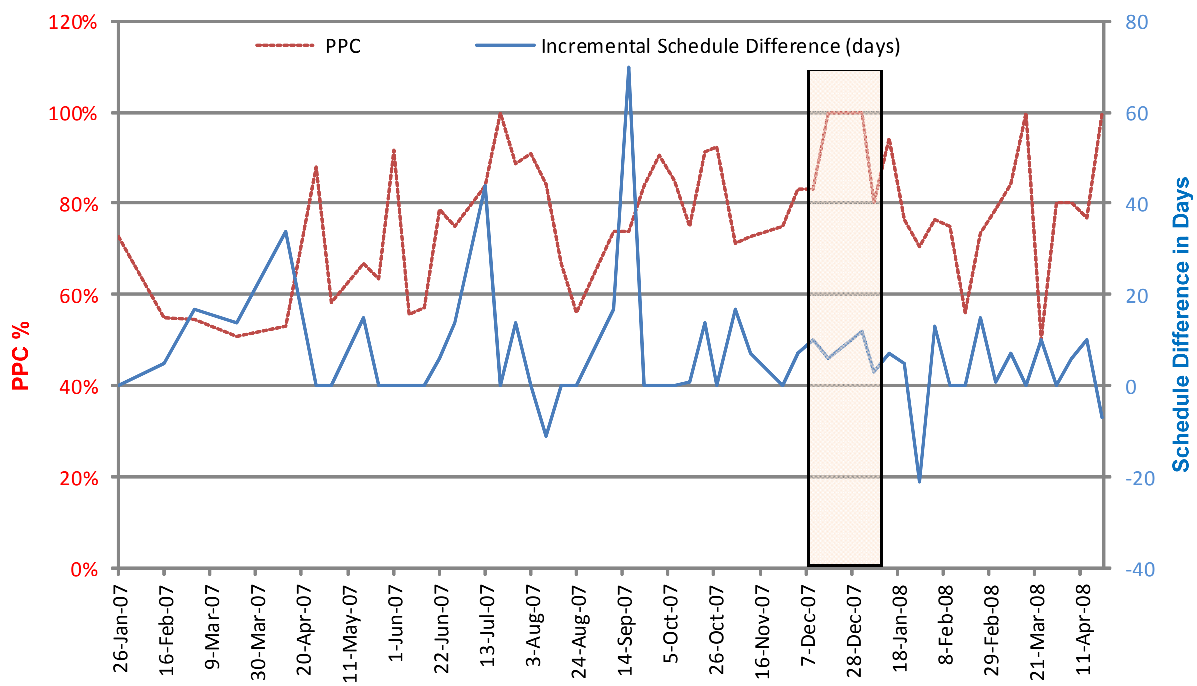

Figure 3: The relationship between Percent Plan Complete (PPC) and incremental schedule difference for case study 2

Results not only show a low correlation of 0.13 between PPC and negative incremental schedule difference but also inconsistencies in the relationship between these two variables. The highlighted areas in Figure 3 show a 100% PPC indicating a successful execution of all the planned weekly work plan tasks. However, the project schedule during the same periods is falling behind and shows slippage from one update to the next.

Hence, some of the executed weekly work plan tasks do not contribute to overall project performance suggesting that a substantial number of these tasks are non-critical or even out-of-sequence. These results show that weekly work plans are not properly founded in the master schedule. In this case PPC did not successfully represent overall schedule performance.

Online Survey

To better describe construction planning practices and the implementation of the Last Planner System, a survey was conducted in collaboration with the Lean Construction Institute (LCI) among Last Planner System users in the US and worldwide[4].

Table 1: Summary of the Last Planner System survey results

Survey Question	Survey Answers				
Span of Lookahead plan developed	6 weeks **62 %**	5 weeks **1 %**	4 weeks **11 %**	3 weeks **18%**	2 weeks **8%**
Tasks maintain the same level of detail throughout the lookahead planning process	Strongly agree **14 %**	agree **33 %**	neither **17 %**	disagree **30 %**	Strongly disagree **6 %**
PPC is an important indicator of project progress	Strongly agree **24 %**	Agree **55 %**	Neither **16 %**	Disagree **4 %**	Strongly disagree **1 %**
Percentage of constraints are Identified and removed at the WWP level	>= 75% **16 %**	>= 50% but<75% **32 %**	>= 25% but<50% **27 %**	<25 % **13 %**	other **12 %**
Analyse reasons for plan failures	no **22 %**	yes & find failure categories **52 %**	yes & find root causes **20 %**		other **6 %**

The survey explores the following issues:

- Performance of the planning process during the four stages of the Last Planner System (master scheduling, phase scheduling, lookahead planning, and weekly work planning).
- Organizational setup of the lookahead process.
- Planning and scheduling methods used in developing the lookahead plan.
- Software programs used to develop schedules at the various levels of the planning system.
- The process of identifying and removing constraints.

[4] The survey and data analyses are reported more fully in (Hamzeh 2009).

- The compatibility between the lookahead plan and the weekly work plan.
- Methods employed for acting on reasons for plan failures.

The survey results helped draw a picture of the methods that the Last Planner System users follow for planning and scheduling and exposed performance issues and areas needing improvement. To illustrate, Table 1 shows that most industry practitioners track only categories of plan failures (e.g., material shortages) but do not perform analysis to uncover root causes and take preventive actions that inhibit the recurrence of such failures. The survey also shows that companies do not give enough attention to identifying constraints and removing them prior to activity execution. Table 1 highlights the major results from the 112 surveys.

Concerns with Current Practice

Research findings from the case studies and the industry survey highlight various issues related to production planning and execution. The results show inadequate implementation of planning processes especially at the lookahead level. Concerns include:

- Deficiencies in employing standardized planning processes required to clearly explain procedures for crucial planning processes such as lookahead planning and the role of the facilitator in engaging last planners.
- Incorrect development of lookahead plans by presenting merely a lookahead filter of activities shown on the master schedule instead of coordinating activities, planning operations, and identifying constraints for removal.
- Sluggish identification and removal of constraints. When constraints requiring a lead time beyond the weekly work plan window are identified late in the process, the chances of removing them prior to task execution are seriously diminished.
- The absence of analyses aimed at finding the reasons behind plan failures. If reasons for failure are not identified, it becomes difficult to prevent the failures from happening again.
- Poor linkage between the master schedule, phase schedule, lookahead plan, and weekly work plan. This can cause PPC to become loosely linked to overall project progress. This reduces the reliability of the planning system and increases the construction team's reactive approach to performing work activities.

Lookahead Planning Suggested Guidelines

To address the aforementioned concerns, a set of guidelines for implementing lookahead planning are presented. These guidelines build on previous work laid out by Ballard (1997), Tommelein and Ballard (1997), Ballard (2000), Ballard et al. (2003), Ballard and Howell (2004), and Hamzeh et al. (2008). However, these guidelines take lookahead planning a step forward by presenting detailed procedures for running the planning process and incorporate metrics to assess performance of the system experimentally[5]. The lookahead planning guidelines presented in this paper extend those in the literature with new refinements derived from research findings and concerns with the current practice. Although

[5] These metrics were first presented by Ballard (1997). This paper renames them, presents a methodology for developing lookahead plans to enable the tracking of metrics, and presents more explicit methods for calculation.

a full understanding of why the rules are not being followed is required, the objective of this paper is to make sure that the rules are adequately stated and understandable.

As a first step in production control, lookahead planning is a vital link between phase schedules and weekly work plans. Lookahead planning makes scheduled tasks ready to be performed, shields activities on the weekly work plan from variations by removing constraints, sizes capacity to work flow, produces a backlog of workable activities, and designs how operations are performed (Ballard 2000, Ballard et al. 2003). Lookahead planning accomplishes the above mentioned goals through three main steps (Ballard 1997, Hamzeh 2009):

- Breaking down tasks into the level of processes then to the level of operations[6]
- Identifying and removing constraints to make tasks ready for execution
- Designing operations through first run studies

In identifying and removing constraints, lookahead planning employs activity screening and pulling. Screening subjects tasks to constraint analysis and culls out those with missing prerequisites such as information, material, previous work, manpower, and space. Pulling makes activities ready by removing constraints and ensuring the availability of prerequisites as per actual site demand.

Figure 4 presents a six-week lookahead-planning process detailing the steps required to perform as the lookahead plan evolves from tasks on the phase schedule to tasks on the weekly work plan. When developing a lookahead plan, the following guidelines and steps help reinforce compatibility between the master schedule and weekly work plans:

Step 1- Six weeks ahead of execution: Tasks enter the six week lookahead plan from the phase schedule (or master schedule if a phase schedule has not been developed). At this stage, gross constraints are evaluated and a plan for removing these constraints is developed. A gross constraint impacts a whole phase and all underlying work in that phase. In construction, typical gross constraints are materials and design information. Although removing constraints can take place anywhere within the six weeks on the lookahead plan, it is desirable to remove constraints (make sure prerequisites can be made available on time) at least two to three weeks prior to executing a task.

Step 2- Between five weeks and four weeks ahead of execution: Activity break down starts by decomposing phase-level tasks / “Boulders” into their underlying work elements expressed in terms of processes / “Rocks” and operations / “Pebbles”. Projects consist of phases, phases of processes, processes of operations, operations of steps, and steps of elemental motions / “Dust”. Elemental motions are not represented in current forms of the Last Planner System, although they may be appropriate analytical units for design of highly repetitive tasks executed under controlled conditions. Steps are defined in the design of operations. Steps are tasks assigned to individuals or sub-teams within work groups.

Activity breakdown goes in parallel with defining operations (e.g., Install unitized curtain wall panels), sequencing work in the most optimal way, coordinating tasks among

[6] The nomenclature used here posits that phase schedules be expressed in terms of processes and that processes are subsequently broken down into operations when scheduled tasks enter into lookahead planning. Processes are assumed to be delimited by handoffs between organizations such as different specialty contractors, whereas operations are assumed to be performed by individual work crews; hence handoffs are between crews, which may belong to the same organization.

project stakeholders, loading operations with resources, sizing load to match capacity, and analyzing tasks for soundness so that prerequisite inputs are ready such as previous work, information, material, labor, and space (Ballard 2000 and Hamzeh 2009).

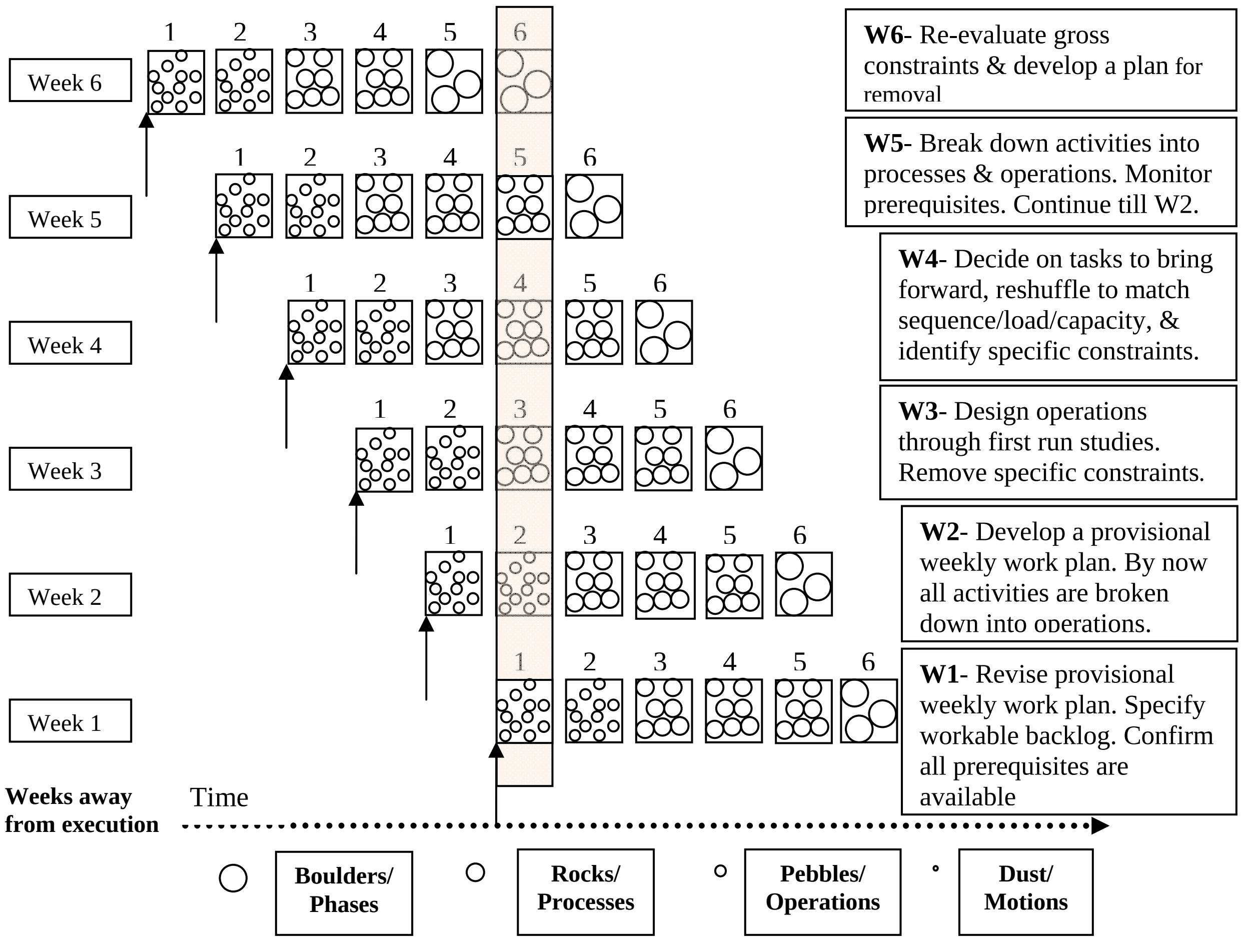

Figure 4: Example six-week lookahead planning process (adjusted from Hamzeh et al. 2008)

Step 3- Three weeks ahead of execution: At this stage the relevant teams design operations using first run studies, identify constraints that appear once tasks are defined as operations, and screen out those tasks they are not confident can be made ready in time. A first run study involves collaborative design of an operation, involving the craft workers who will perform the operation for the first time, and then testing that design on the first run against safety, quality, time and cost criteria. It involves understanding the work involved, the skills and resources needed, and the interactions with other operations. Operations requiring explicit design are those that are new, critical, or repetitive (Ballard and Hamzeh 2007). Virtual and physical prototyping may be used earlier to design these operations. Using the first run to test the adequacy of an operation's design is valuable even for operations that occur only once on a project, but can yield benefits to the project itself, as opposed to future projects, in the case of repetitive operations.

Step 4- Two weeks ahead of execution (referred to as WK2): Lookahead plan activities are broken down and detailed to level of operations/steps as they move closer to execution. Accordingly, when activities are two weeks away from execution, they will match the detail required for production as shown on the weekly work plan; i.e., they will be expressed as tasks to be performed by specific work crews. Although steps can be decomposed into elemental motions expressing the jobs of sub-crews they are not recorded in weekly work plans, but are left to be controlled by the front line supervisor, aka “last planner”. While tasks on the weekly work plan are expressed in days for most construction projects, this can change for special types of projects such as shut down operations, or for projects that are ready to meet the challenge of planning to a tighter timetable. Specific constraints, related to specific tasks, are removed prior to the execution week. Tasks that are constraint-free join the fall back / follow on work list (list of ready tasks to work on when extra capacity is available). Tasks on the workable backlog may be selected for inclusion in the weekly work plan if they meet the quality criteria as mentioned in step 5.

Step 5- One week ahead of execution (referred to as WK1): At this stage, a provisional weekly work plan is prepared from (WK2) gauging tasks against quality criteria of a) definition (well defined scope), b) soundness (unconstrained), c) sequence (in proper sequence), d) size (matching size and capacity), and e) learning (use metrics to monitor and improve performance). Tasks that are critical, made ready, or can be made ready in the upcoming week are incorporated in the weekly work plan within available capacity. Made ready and non-critical tasks are placed on the fall back / follow on work list to be performed in case of extra capacity, either from completing critical tasks sooner than expected, of from discovering a constraint that cannot be removed in the plan period (Ballard 2000, Hamzeh 2009).

Metrics to Measure the Performance of Lookahead Planning

Two metrics are proposed to monitor the performance of the lookahead process: (i) Tasks Anticipated (TA) and (ii) Tasks Made Ready (TMR). TA measures the percentage of tasks anticipated on the lookahead plan two weeks ahead of execution. TMR measures the performance of lookahead planning in identifying and removing constraints to make tasks ready for execution (Ballard 1997 and Hamzeh et al. 2008). TMR (i, j) measures the percentage of tasks anticipated on the lookahead plan i weeks ahead of week j, with week j being the week of execution (the week covered by the weekly work plan).

To better explain these metrics, Figure 5 presents an example for calculating TA and TMR by showing: (a) a lookahead plan two weeks away from execution (WK2, 06/08/12), (b) a weekly work plan at the beginning of the execution week (WWP, 06/15/12), and (c) an executed weekly work plan at the end of the week (WK0, 06/20/12).

Dividing the number of tasks completed at WK0 (13) by those planned (18) (ignoring tasks completed out of the fall-back / follow-on work list[7]) gives a 13/18 = 72% PPC. Examining the weekly work plan (WWP) shows that out of the 18 tasks that made their way to the weekly work plan, only 14 were successfully anticipated on the lookahead plan two weeks

[7] This might skew somewhat the relationship between PPC and project progress, but is consistent with the purpose of the PPC measurement; namely, to measure the extent to which near term work plans predict future states of the project.

away from execution (WK2). These 14 successfully anticipated tasks at (WK2) result in a TA of 14/18 = 78%. Comparing the lookahead plan two weeks away from execution (WK2) and the executed weekly work plan (WK0) shows that out of the 20 tasks indicated on the lookahead plan only 11 have been completed or done, resulting in a TMR (2,0) of 11/20 = 55%. TMR (2,0) counts tasks that were made ready between WK2 and WK0 (Hamzeh 2009).

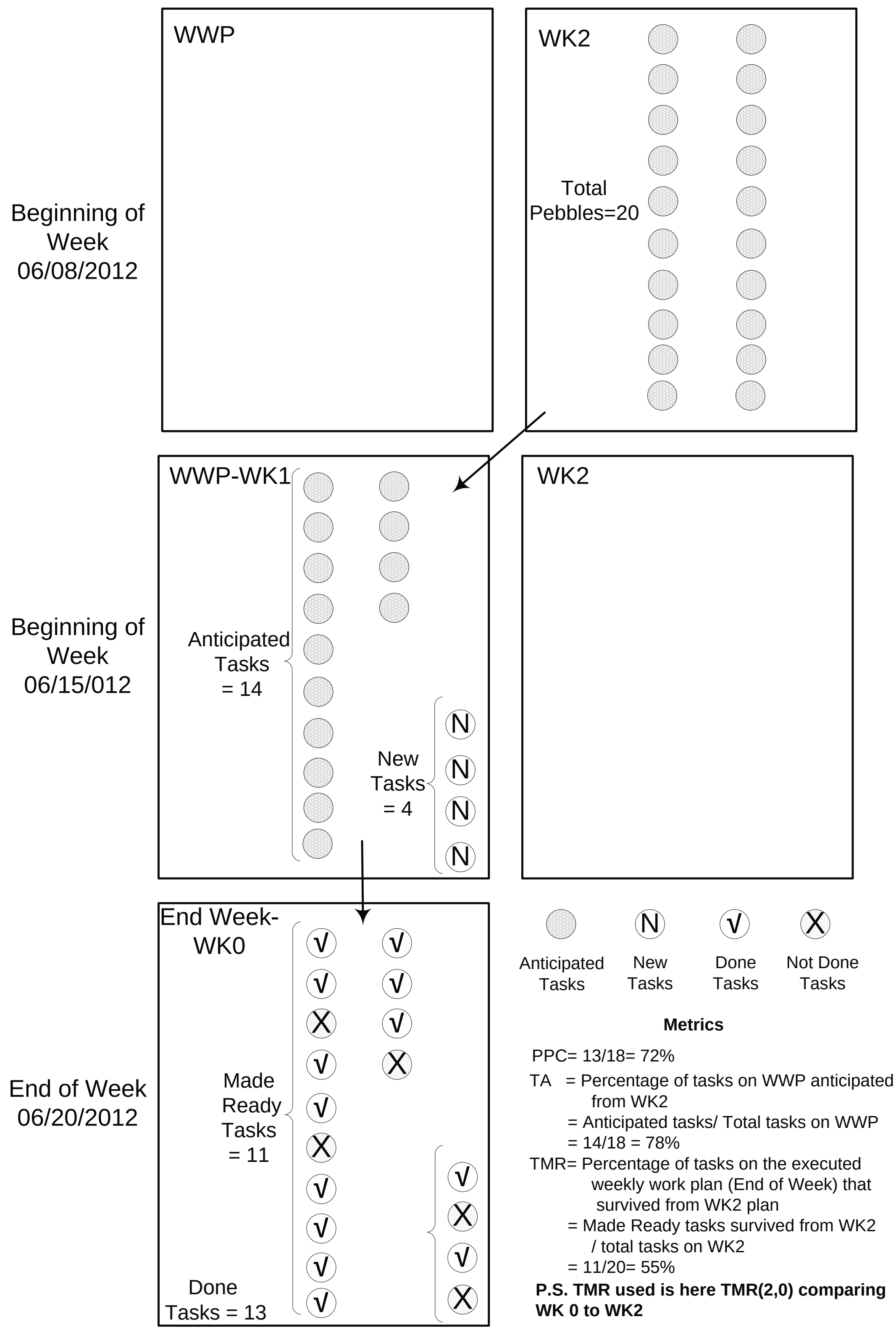

Figure 5: Measuring Tasks Anticipated (TA), Tasks Made Ready (TMR), and Percent Plan Complete (PPC)

In practical application, TA and TMR indicate the production team's ability to plan tasks and make them ready for execution. TA expresses foresight in anticipating tasks and identifying constraints. Establishing foresight is only one part of lookahead planning; it should be combined with screening, proactive removal of constraints, and prioritizing tasks for execution, which are captured by measuring TMR. TMR thus measures the success in identifying and removing constraints ahead of time contributing to an increase in task completion.

One hypothesis that can be addressed in future studies is that improving the performance of lookahead planning (i.e., increasing TA and TMR) results in improving the reliability of weekly work plans (i.e., increasing PPC). Another hypothesis to be tested is that improving the reliability of weekly work plans (i.e., increasing PPC) will improve overall schedule performance (i.e., reduce delays on the master schedule).

Conclusions and Recommendations

This paper addresses how the construction companies surveyed implement the Last Planner System and practice production planning and control. It pinpoints deficiencies in current planning systems mainly due to lack of standardized planning processes, incorrect lookahead planning practices, sluggish identification and removal of constraints, and absence of analysis for plan failures. It advises a standardized practice to support a strong linkage between lookahead planning and activity execution.

Results suggest that when lookahead planning is not properly implemented, weekly work plans are not properly linked to long term plans and Percent Plan Complete (PPC) is not a reliable indicator of 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 planning process by increasing the linkage between weekly work plans and the project schedule. This is accomplished through performing three main steps: (1) breaking down tasks into the level of processes then to the level of operations, (2) identifying and removing constraints to make tasks ready for execution, (3) and designing operations through first run studies.

The paper recommends metrics to assess the performance of lookahead planning and illustrates the way they are computed. Monitoring TA and TMR is expected not only to cause improved performance of the lookahead process but also to shed light on the impact TA and TMR can have on PPC. This subject demands further research to study the nature of the relationship between performance of lookahead planning, performance of weekly work planning, and overall project performance.

Future Research

Future research should include testing the hypotheses on which the Last Planner System is structured:

- If lookahead tasks are drawn from a phase schedule structured to achieve the project end date and intermediate milestones, and if lookahead planning makes ready what SHOULD be done, and if weekly work plans are formed from what CAN be done among what SHOULD be done in the order of criticality, PPC will vary with project progress.

- Improving the performance of lookahead planning (i.e., increasing TA and TMR) results in improving the reliability of weekly work plans (i.e., increasing PPC).
- Improving the reliability of weekly work plans (i.e., increasing PPC) will improve overall schedule performance (i.e., reduce delays on the master schedule).

Future research should also explore reasons why those who implement the Last Planner do not follow the recommended rules or guidelines. Is it because those rules are not understood, because practitioners do not understand the system as a whole of interdependent parts, because they are too easily satisfied with the gains that come from partial and incomplete implementation, because the rules are infeasible in actual industry conditions, or perhaps because of some other reason not yet identified?

We urge both academic researchers and industry practitioners to join us in this important research.

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