LOOKAHEAD PLANNING: THE MISSING LINK IN PRODUCTION CONTROL

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Abstract
Lookahead planning is one of the decision functions that constitute production control systems. It stands between overall project coordination schedules and short term crew level commitments, shaping work flow and screening out scheduled activities that "should" but cannot be done and thereby improving the success rate of completing the tasks assigned in weekly and daily plans. When measured against such objectives, current industry lookahead planning is poorly performed. A case study is presented to illustrate current procedures and performance, and suggestions are offered for improvement.

Keywords: lean construction, lookahead, production control

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PREFACE

This paper reports on one aspect of a larger research program devoted to the topic of production control in construction. A differentiating characteristic of this research is its selection of the production unit and the assignment as the unit of analysis. Another differentiating characteristic is its conceptual framework, which posits planning as a process of reducing uncertainty and maximizing throughput, counterposing plan reliability to resource redundancy as alternative strategies for managing in conditions of uncertain work flow. For prior publications from this research program, see Ballard and Howell (1997).

INTRODUCTION

Most construction projects issue a 'master' schedule at or near the beginning of the construction phase, extending from beginning to end of the project. Such schedules may serve many purposes, from long term coordination to specifying terms of payment. However, such initial, total project schedules cannot be accurately detailed too far into the future because of lack of information about actual durations and deliveries. Consequently, most construction projects use some form of short term schedule to coordinate and direct the various trades and crews working on the job. These schedules are often called "lookahead schedules" because many look ahead several weeks into the future. Practice varies widely regarding the extent of lookaheads, their level of definition of activities relative to master schedules, the frequency of issue, their update and use in learning from experience, etc.

Lookahead schedules are commonly used in the construction industry in order to focus management attention on what is supposed to happen at some time in the future, and to encourage actions in the present that cause that desired future. However, lookahead schedules are rarely conceived as having the specific purpose of producing sound assignments, nor are procedures provided for lookahead processes. Usually, a lookahead schedule is simply a drop out from the higher level schedule, occasionally at a greater level of detail, but with no screening of scheduled activities against soundness or other criteria. The prevailing idea seems to be simply that thinking ahead is beneficial.

In Melles' and Wamelink's model, lookahead planning is one of the decision functions that constitute production control systems (Melles and Wamelink 1993). In previous papers (Ballard and Howell 1994), lookahead planning has been differentiated from commitment planning, which often takes the form of weekly work plans produced for each crew or subcrew of each trade. Measurement of the PPC (percent plan complete: number of completed assignments divided by the total number of assignments) of weekly work plans has revealed a chronic and widespread problem of low plan reliability. This problem is of vital importance because of its adverse impact on labor productivity both of the production unit that has a low PPC and those downstream production units which inherit the uncertainty passed onto them. Project durations are also extended by low plan reliability, because of the extended durations of installation activities and because of the time and material buffers that the industry has come to rely on to compensate for uncertainty (Howell and Ballard 1995).

Lookahead planning is proposed as the key to improving PPC, and consequently the key to reducing project cost and duration. In this paper, a case study is used to illustrate efforts to improve PPC through the early restructuring of a project production control system.

MECHANICAL CONTRACTOR CASE

In late 1996-early 1997, a large, highly successful mechanical contractor began to restructure its production control system, working initially on a pilot project which employed approximately 50 plumbers, pipefitters, and sheet metal (HVAC) workers. Previously, weekly work plans had been produced, but were mostly simple lists created without explicit objectives and procedures. Lookahead shedules had not been produced at all. Master CPM schedules were just being introduced into the company, but had been conceived as the vehicle for detailed directing of operations, and so were issued at the beginning of projects, then rarely, if ever, updated. The contractor's consultants advised them to work first on improving the quality of assignments in weekly work plans, then on the lookahead planning that is supposed to produce and maintain an inventory of quality assignments. Other aspects of the restructuring have yet to be initiated and will not be presented in this paper.

Figure 1 is a sample weekly work plan produced early in the restructuring process. It has several positive features, including detailed definition of assignments, identification of assignments by individuals, schedules for each assignment, and identification of backlog work if needed to replace higher priority assignments that could not be done, or to allow utilization of available labor capacity if all priority tasks should be completed. The sample shown has been statused at the end of the week, showing the percent complete of each assignment and the reason for failing to fully complete those assignments statused at less than 100%. Note that 4 of 9 assignments were 100% completed.

1 WEEK PLAN

PROJECT: Pilot — **FOREMAN: PHILLIP**

DATE: 9/20/96

ACTIVITY	Est	Act	Mon	Tu	Wed	Thurs	Fri	Sat	Sun	PPC	REASON FOR VARIANCES
Gas/F.O. hangers O/H "K" (48 hangers)			xxxx Sylvano, Modesto, Terry	xxxx						0%	Owner stopped work (changing elevations)
Gas/F.O. risers to O/H "K" (3 risers)					xxxx Sylvano, Mdesto, Terry	xxxx	xxxx	xxxx		0%	Same as above-worked on backlog & boiler blowdown
36" cond water "K" 42' 2-45 deg 1-90 deg			xxxx Charlie, Rick, Ben	xxxx	xxxx					100%	
Chiller risers (2 chillers wk.)						xxxx Charlie, Rick, Ben	xxxx	xxxx		20%	Matl from shop rcvd late Thurs. Grooved couplings shipped late.
Hang H/W O/H "J" (240'-14")			xxxx Mark M., Mike	xxxx	xxxx	xxxx	xxxx	xxxx		100%	
Cooling Tower 10" tie-ins (steel) (2 towers per day)			xxxx Steve, Chris, Mark W.	xxxx	xxxx	xxxx	xxxx	xxxx		70%	Some work in next week's sched. was included this week.
Weld out CHW pump headers "J" mezz. (18)			xxxx Luke	xxxx	xxxx	xxxx	xxxx	xxxx		100%	
Weld out cooling towers (12 towers)			xxxx Jeff	xxxx	xxxx	xxxx	xxxx	xxxx		60%	Eye injury. Lost 2 days welding time
F.R.P. tie-in to E.T. (9 towers) 50%			xxxx Firt, Packy, Tom	xxxx	xxxx	xxxx	xxxx	xxxx		100%	
WORKABLE BACKLOG Boiler blowdown-gas vents -rupture disks											

Figure 1 9/20/96 Weekly work plan.

Figure 2 is a later weekly work plan by the same front line supervisor showing the addition of a column for "Make Ready Needs", a response to the fact that front line supervisors have responsibilities for making assignments ready to be carried out, even <u>after</u> they appear on weekly work plans. Note that 3 of 3 assignments were 100% completed.

1 WEEK PLAN												Crew Size: 5
PROJECT: Pilot												FOREMAN: PHILLIP DATE: 11/25/96
ACTIVITY	**MAKE READY NEEDS**	**Est**	**Act**	**Mon**	**Tu**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	**PPC**	**REASON FOR VARIANCES**
Weld out CHW 1st Flr "F" in Fab.	Material on site			xxxx Cruz, Tim							100%	
Put shoes under & tack hangers in "J" bldg. 200 deg. HW, approx. 54	Need 18 more insul. shoes (at yard)			xxxx Hank, Cruz	xxxx	xxxx					100%	
Pre-punch "J" & "F" 1st & 2nd Flr	Material on site			xxxx Phillip, Gary, Tim	xxxx	xxxx					100%	
WORKABLE BACKLOG												

Figure 2 11/25/96 Weekly work plan

Figure 3 shows the PPC for all the mechanical contractor's crews from the week of 10/7/96 through the week of 1/20/97, when the project was entering the turnover stage. In that period, average PPC improved by roughly 10%, from 55% to 65%. The project was extremely successful, with a gross margin (operating profit) of approximately 30%. Some of that financial performance was clearly a function of pricing, but company and project managers attribute a large part to the improvement in plan reliability and have committed to extending the production control system to all its projects.

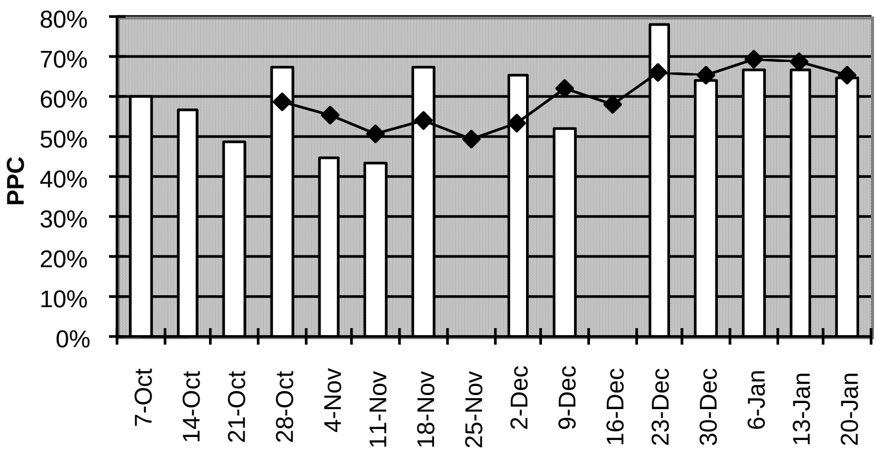

Figure 3 Pilot project PPC with 4 week moving average.

One of the reasons why PPC improved is because reasons (see Figure 4) for failing to complete assignments were tracked and attacked. 347 of 587 assignments were completed as planned over the entire study period, for an average PPC of 59%.

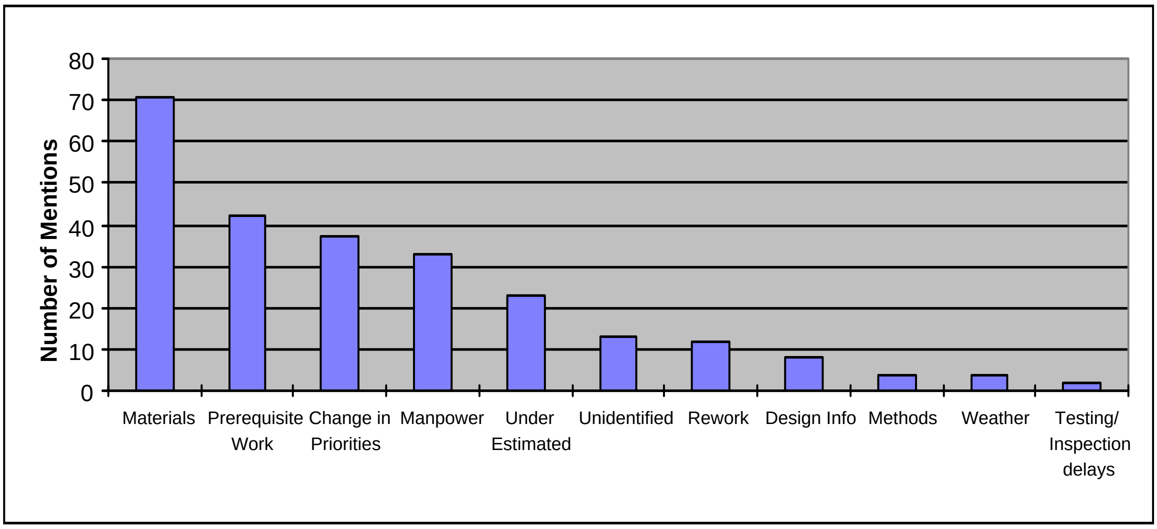

Figure 4 Reasons for not completing assignments.

Of the 249 assignments that were not fully completed, 71 were because of late or defective materials, 42 because prerequisite work was not completed, 37 because of changes in priorities, 33 because of absenteeism or accident (manpower), 23 because of failure to accurately estimate the amount of labor time required to execute assignments, and so on. Over the course of the project, improvement was made in the areas of materials (Figure 5), prerequisite work (Figure 6), manpower (Figure 7), and overplanning (Figure 8). These gains were partially offset by increases in the number of changes in priorities later in the project (Figure 9).

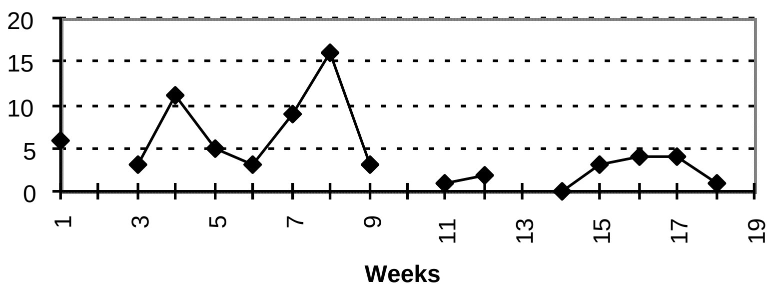

Figure 5 Materials.

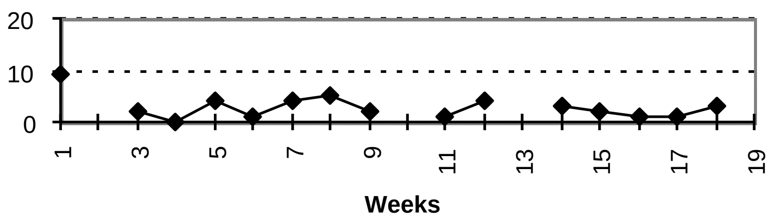

Figure 6 Prerequisite work.

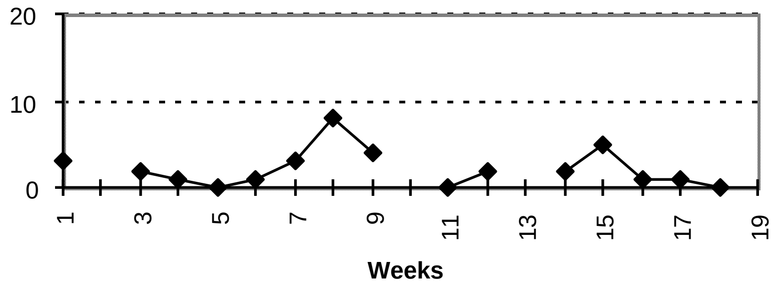

Figure 7 Manpower.

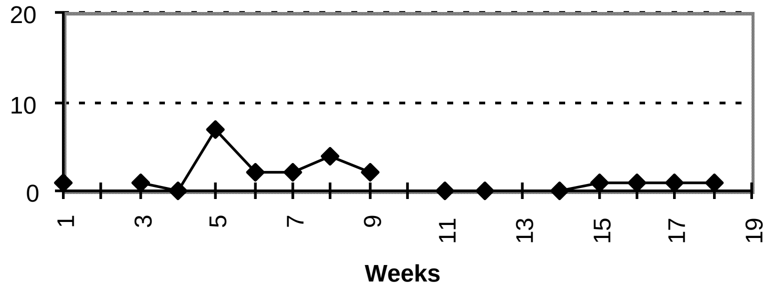

Figure 8 Underestimating durations.

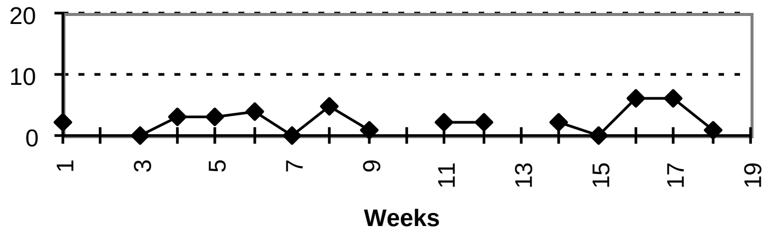

Figure 9 Changes in priority.

Weekly work plans were required not only of the construction crews, but also from individual supervisors, managers, and engineers. Investigation of materials problems revealed that project engineers responsible for expediting and other materials-related tasks were not always on the same page with production. Project engineers began to present their weekly work plans for review in staff meetings (which were also instituted as a regular weekly event) and to post them on their office doors. Coordination improved as a result. Project engineers reported that they were relieved to have a mechanism for knowing that they were doing the right thing. The material handling supervisor was equally excited to have a way of identifying and prioritizing his tasks. He received and reviewed each superintendent's lookahead schedule and each foreman's weekly work plan, then interviewed each of them to determine exactly what he needed to get done and when.

Additional actions on reasons included: meeting with the fabrication shop to improve deliveries, communicating lookahead schedules and weekly work plans to other contractors each week, and asking workers to give a week's notice of non-emergency absences.

LOOKAHEAD PLANNING: PURPOSES

The mechanical contractor had a centralized detailing crew and fabrication shops at its home office. Planning must obviously extend beyond one week ahead in order to coordinate with such internal suppliers, with external suppliers, as well as with other trades. Figure 10 shows a typical 5 Week Lookahead, so-called because it extends five weeks into the future, although next week is not shown. Some of its relevant features are the identification of assignments by front line supervisor and crew, the scheduling of those assignments, and the identification of actions needed to make the assignments sound as regards materials, design, or prerequisite work. It was issued Friday, 1/3/97.

PROJECT: Pilot — **5 WK LOOKAHEAD**

ACTIVITY	1/13/97						1/20/97						1/27/97						2/3/97						NEEDS
	M	T	W	T	F	S	M	T	W	T	F	S	M	T	W	T	F	S	M	T	W	T	F	S	
Scott's crew																									
"CUP" AHUs-10 CHW, 2 HW	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X								CHW delivers 1-8-97 thru 1-13.HW delivers 1-20.
Punch, label, & tag AHUs															x	x	x								Materials on site
Ron's crew																									
DI Steam to Humidifier			x	x	x																				Materials on site
DI Steam Blowdown	x	x																							Check material
DI Steam Cond. to coolers (13)							x	x	x	x	x		x	x	x	x	x		x	x	x				Material on site
Charles' crew																									
200 deg HW 1-"H"	x	x	x																						Matl delivery 1-8-97
200 deg HW 1-"B" & 1-"D"							x	x	x	x	x		x	x	x	x	x								Release matl for 1-15-97
1st flr 200 deg HW guides & anchors	x	x	x	x	x								x	x	x	x	x								Material on site. Need West Wing flr covered.
Richard's crew																									
2-"A" HW & CHW	x	x	x	x	x																				Control valves for added VAV coils
CHW in C-E-G tunnels	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x								Need tunnels painted & release materials
Misc FCUs & cond. drains in "I", "J", & "K" 1st flr							x	x	x	x	x		x	x	x	x	x								Take off & order materials
Punch, label & tag							x	x	x	x	x		x	x	x	x	x								Material on site

Figure 10 5 Week lookahead schedule.

The following purposes for lookahead planning were identified:

1) Shape work flow in the best achievable sequence and rate for achieving project objectives that are within the power of the organization at each point in time.
2) Match labor and related resources to work flow.
3) Produce and maintain a backlog of assignments for each frontline supervisor and crew, screened for design, materials, and completion of prerequisite work at the CPM level.
4) Group together work that is highly interdependent, so the work method can be planned for the whole operation.
5) Identify operations to be planned jointly by multiple trades.

LOOKAHEAD PLANNING: PROCEDURE

The steps involved in the process each week are presented in Figure 11:

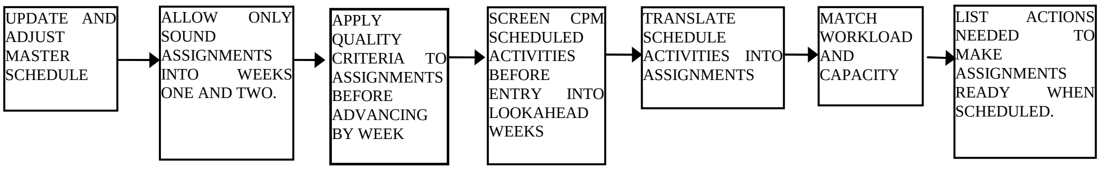

Figure 11 Lookahead planning procedure.

Step 1: Enter the latest status and forecast information into the project master schedule. Adjust starts, completions, sequences, and durations accordingly.

Step 2: Do not allow any assignments into week one that are not ready, except by project management decision. Ask the foreman if each assignment can be completed in week one, recognizing that he/she may have to determine completion of prerequisite work at the item level, arrange for prework such as scaffolding, and coordinate the use of shared resources such as equipment or special tools. Allow that amount of work into week one that can be completed in the week.

Step 3: Examine the remaining weeks in the lookahead, except for the last, moving from present to future. Screen out any assignments that cannot be made ready when scheduled. Try to maintain for each crew an amount of assignments twice that which can be completed in a week.

Step 4: Identify those activities scheduled to start or complete in the lookahead week (e.g. Week 5 for the mechanical contractor) and screen out any activities that you do not know can be made ready to assign when scheduled. Take into consideration the status of design, including pending changes or open issues, the availability of materials and components needed for each activity, and the probability that prerequisite work will be complete when needed.

Step 5: Translate lookahead week activities into the language of assignments, grouping highly interdependent operations that should be planned as a whole, and identifying operations to be planned jointly by multiple trades.[1]

Step 6: Calculate the earnable manhours or otherwise quantify the labor content of the work in the lookahead week. If that amount of work falls below the amount needed to maintain schedule and if you will have the labor capacity to do that amount of work, advance work from the master schedule to the extent practical. If the resultant amount of work falls below the current work force, reduce the work force, or decide how to use the excess labor time. If that amount of work exceeds the current or projected work force, decide whether or not to increase labor to accelerate progress.

Step 7: Produce a list of actions needed to make assignments ready when scheduled.

[1] Different trades have different primary installation units. Piping and plumbing use isometrics, while electricians talk in terms of cable pulls and junction boxes. Each trade should have a list of the work within its scope expressed in terms of its own installation units in order to determine material and labor requirements. A convenient tool is a database of such units, with fields allowing quantifying, assigning and tracking. Properly structured, the database makes work flow visible and allows for it to be managed.

Work that is allowed into the lookahead period is evaluated each week before being permitted to advance further. As stated in Step 3, the goal is to maintain a buffer of roughly two weeks' worth of sound assignments, or to adjust the labor force to actual work flow when that buffer cannot be maintained. A two week buffer has proven to be a practical goal, although some variation in size can occur without impacting productivity. There may well be cases in which PPC is consistently high that require less than two weeks' worth of work for a production unit. However, to properly size the buffer, it is necessary to first determine the actual productive capacity of the unit and the extent of variation in productivity over time.

LOOKAHEAD PLANNING: PERFORMANCE MEASUREMENT

All involved agreed that the next stage in the development process should concentrate on improving lookahead planning. To help achieve that improvement, some type of performance measurement is needed. How well lookahead planning was done on the mechanical contractor pilot project has thus far been assessed in the following ways:

1. Subjective evaluation by project superintendents/managers and consultants.
2. Measuring the extent to which weekly work plan assignments previously appeared on lookahead schedules-Assignments Anticipated.
3. Measuring the extent to which assignments that appeared on lookahead schedules appeared on weekly work plans when scheduled-Assignments Made Ready.
4. Tracking the change over time of scheduled dates for specific assignments using Time/Time charts.

Suppose we are interested in the week of 1/6/97. Consider the work plan for that week to be the plan for Week One, the lookahead schedule issued on 12/30/96, in which 1/6/97 is the first of the lookahead weeks, to be the plan for Week Two, and the lookahead schedule issued 12/23/96, in which 1/6/97 is the second of the lookahead weeks, to be the plan for Week Three. PPC measures the percentage of Week One assignments completed, AA-Wk1 measures the percentage of those assignments that were anticipated one week ahead, and AA-Wk2 measures the percentage of those assignments that were anticipated two weeks ahead. As shown in Figure 12, in the six week period from 12/23/96 through 1/27/97, superintendents identified one week ahead (AA-Wk1) only 52% of the assignments that appeared on weekly work plans in the week following. In the same period, AA-Wk2 was only 40%; i.e., only 40% of the assignments that appeared on weekly work plans for 1/6/97 were scheduled for that date on 12/23/97.

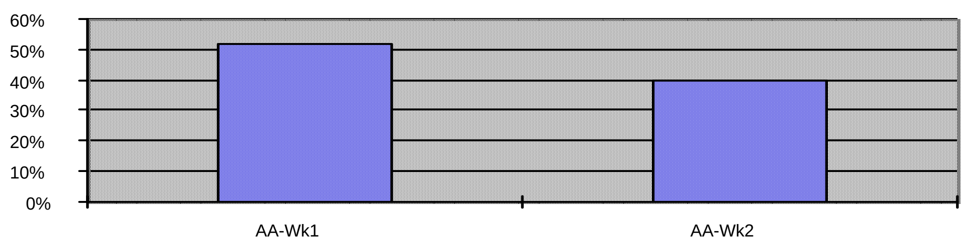

Figure 12 Assignments anticipated.

The ability to anticipate assignments is critical because assignments cannot be "made ready" if they are not identified. Another critical aspect of lookahead planning is the ability to make ready those assignments that are identified. Thus far, categorization has been done defining "made ready" as equivalent to "appearing on the right weekly work plan." In further analysis, the intention is to make an additional screening against the PPC of the weekly work plan itself, so we can screen out assignments that obviously were not made ready even though they appeared on weekly work plans. That would even further reduce the percentages shown in Figure 13. AMR-Wk1=the number of assignments that were scheduled for the plan week on lookaheads one week ahead divided by the number of assignments on the weekly work plan. AMR-Wk1 averaged 59% over the six week period. AMR-Wk2 averaged 49% over the same period.

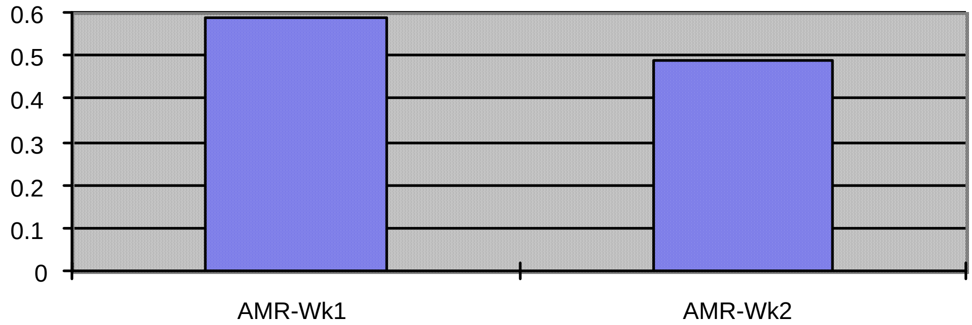

Figure 13 Assignments made ready.

A last method of analysis, time/time charts[2], has so far been used sparingly. Scott was a frontline supervisor working for superintendent Larry on the pilot project. One of Scott's assignments on his weekly work plan for 1/20/97 was "Finish AHU 274.1." As shown in Table 1, that assignment first appeared on the lookahead schedule Larry issued 12/30/96, and was scheduled for the week of 1/6. The assignment appeared on Larry's next lookahead schedule (issued 1/6/97) and was scheduled for 1/13. On Larry's lookahead issued 1/13/97, the assignment was scheduled for 1/20, and in fact was done on 1/20 according to Scott's statused weekly work plan for that date. The time/time charts shown in the tables below have issue dates vertically and scheduled dates horizontally.

Table 1 Time/time chart for "Finish AHU 274.1".

Issue Date/ Scheduled Date	**1/6/97**	**1/13/97**	**1/20/97**
12/30/96	x		
1/6/97		x	
1/13/97			x
1/20/97			Completed

[2] The idea for time/time charts came to the author from Mike Vorster at Virginia Tech by way of Greg Howell, who also had a hand in the matter.

Table 2 shows the changes over time in the schedule for the assignment “Chemical Feed System”, which the superintendent might have realized was far too big for a single assignment. In fact, it was eventually divided into multiple parts and completed over a number of months.

Table 2 Time/time chart for “Chemical Feed System”.

	12/16	**12/23**	**12/30**	**1/6**	**1/13**	**1/20**	**1/27**	**2/3**
12/9	x	x	x					
12/16		x	x	x	x			
12/23			x	x				
12/30				x				
1/6						x	x	x
1/13						x		
1/20								x
1/27								Completed

Some details about materials-related problems can be revealed by time/time charts such as the one shown in Table 3 for the assignment “Raise 200 degree HW on 1st flr West Wing and reconnect ends.” In the lookahead schedule issued 12/30, the superintendent noted “release for delivery 1/9.” However, in the next lookahead schedule, he noted “release material for 1-16-97.” Obviously, the materials could not be acquired when he first wanted them. In the lookahead issued 1/13, he notes “materials on site” and scheduled the work to be done the week of 1/20. In fact, the work did not begin until 1/27, and was not entirely completed until the following week for lack of a control valve and a globe valve, according to the weekly work plan.

Table 3 Time/time chart for “Raise 200 degree HW....”.

	1/13	**1/20**	**1/27**	**2/3**
12/30	x	x		
1/6		x		
1/13		x	x(5 days)	
1/20		x	x(2 days)	
1/27			90% completed	Completed (5 days)

Some assignments were completed precisely on schedule. Table 4 shows one example, for the assignment “Tie-in HEX-2 on 1st Flr Admin Bldg.” The assignment was not anticipated until two weeks prior to scheduled start, but its scheduled start remained the same the next week, and the assignment was completed as scheduled the following week.

Table 4 Time/time chart for “Tie-in HEX-2 on 1st Flr Admin Bldg”.

	1/27
1/13	x
1/20	x
1/27	Completed

LOOKAHEAD PLANNING: ANALYSIS OF DEFICIENCIES

All means of evaluating lookahead planning suggest that it needs major improvement. Far from providing a flow of ready work for selection in weekly work plans, there appears to have been a disjunct between commitment planning and lookahead planning. This appearance is supported by examination of the weekly work plans produced by Richard, the front line supervisor with the highest PPC. Richard divides work into different assignments on his weekly work plans than did his superintendent on the lookahead schedules that are supposedly his source of information. Richard often refuses to schedule work when his superintendent obviously expects him to do so. Richard’s average PPC was approximately 90%, while the next closest was below 70%. His superintendent has testified that the productivity of Richard’s crew is consistently equal to or better than that of other crews, indicating that he is not purchasing higher PPC by selecting less work. In fact, Richard came the closest to following the rule “Only make workable assignments.” Others made assumptions or placed bets about the soundness of the assignments listed on their weekly work plans.

Why bother to improve lookahead planning? Why not make all front line supervisors operate like Richard? For the most part, Richard can protect his crew from failures in work flow management by refusing to make poor quality assignments, but he cannot overcome the negative impact on the project of failing to do critical tasks when they need to be done in order to reduce overall project duration. In addition, he cannot create ready work if the missing ingredients are either outside his power to acquire or have lead times greater than his personal ‘lookahead’. If sequence were irrelevant and if labor capacity could always be matched to work load, simply shielding production units in the weekly work planning process would be sufficient. However, sequence is relevant and productivity can suffer from insufficient load, so lookahead planning is necessary. How can lookahead planning be improved?

Anticipating assignments would be helped if activities on the master schedule could be easily divided into operations, which in turn could be divided into assignments by location or quantity. Master schedule activities tend to be expressed in terms of facility components, often divided by location, e.g., “Prefab MP Ductwork-Admin 1flA.” In order to identify the various tasks that must be performed in order to construct that component in that location, it is necessary to design at least a rudimentary work method.

As regards making assignments ready, to the extent that a bill of materials and design documents can be associated with each scheduled activity, the ultimate assignment can be made sound as regards materials and design. However, it is not so easy to identify the temporary structures and materials needed or to determine the prerequisite work that must be completed beforehand. These require thinking through the scheduled activity as an operation or process, i.e., deciding how the work will be done, in what circumstances, with what material staging areas, with what adjacent trades, etc. The work of process modelers might be helpful in this regard, specifically those who correlate standard processes with facility components and build up master schedule activities from those processes (Odeh 1992). In any case, it appears that a key to improved lookahead planning is methods planning (the subject of later papers in this research program).

The objectives posed for lookahead planning were to shape work flow, match load and capacity, maintain a backlog of sound assignments, and identify operations. Pilot project lookahead planning did not adequately accomplish any of these objectives. Procedures were not sufficiently developed and superintendents were not adequately trained. Superintendents did not have the necessary information and neither did their “suppliers” (detailers, fabrication shops, vendors, trades doing prerequisite work, project engineers, etc.) have the information needed to coordinate fabrication and deliveries with assignments that were otherwise sound. Superintendents and their "suppliers" did not share the same model of production control and consequently were not fully cooperative. The amount of time and energy available for planning may also have been a factor. Planning and control are traditionally understaffed on construction projects, and no changes in staffing were made to support the new production control system.

LOOKAHEAD PLANNING: A STRATEGY FOR IMPROVEMENT

Next steps in the development of lookahead planning should include:

1. Detailing lookahead planning procedures through experimentation.
2. Assembling the relevant players to agree on planning procedures and information flow.
3. Training system participants in the procedures.
4. Providing additional support where needed, e.g. consider assigning planners to superintendents.
5. Developing means for sharing information between construction and its suppliers, e.g., post project and fabrication shop schedules on a shared network.
6. Exploring attempts to use process modeling as scheduling tools.
7. Aligning internal suppliers with the site production control system and philosophy, e.g., restructure fabrication shops away from mass production model toward one-piece flow.

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