



Lean Construction Institute
Transforming Design and Construction

THE LAST PLANNER PRODUCTION SYSTEM WORKBOOK

**Improving Reliability
in Planning and Work Flow**

**Version 2.0
March 2007**

**Lean Construction Institute
www.leanconstruction.org**

**Project Production Systems Laboratory
University of California, Berkeley
P2SL.berkeley.edu**

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Lean Construction Institute

www.leanconstruction.org

Any feedback on this workbook is most welcome. Please address your mailing to Iris Tommelein at tommelein@ce.berkeley.edu or Glenn Ballard at ballard@ce.berkeley.edu.

Version 1.0, the original form of this document, was mainly produced by Iris Tommelein, with help from Glenn Ballard and Gregory Howell. Version 2.0, a substantial revision, was mainly the work of Farook Hamzeh, then a PhD student at the University of California, Berkeley; with help from Glenn Ballard.

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FOREWORD

During the past several years a transformation has occurred in American industry. By implementing the Lean Production Theory (LPT) developed by the Toyota Motor Company and thereby moving away from mass production, many firms in the U.S. and throughout the world have found the key to drastically reducing cost while increasing value and enjoying a greater profit margin.

Through the conception of the Last Planner by Glenn Ballard and Greg Howell, combined with descriptive as well as experimental research conducted by the Lean Construction Institute (LCI), a similar theory of production is now being developed specifically for the Architecture-Engineering-Construction (AEC) industry. Lean Construction embodies a philosophy of production management that is often contrasted to mass production and craft production. While the construction industry has adopted elaborate techniques for project and contract management, by comparison, the management of production has been neglected. It can be argued that construction remains essentially a craft form of production. Our industry develops one-of-a-kind custom prototypes. The AEC industry has never been a mass producer. Nevertheless, the achievements of manufacturing have triggered development of production management thinking and techniques in the design and construction of capital facilities. While the translation of LPT certainly is not automatic, the development of an AEC production theory is sorely needed to help manage and better integrate the AEC product and process development cycle in order to provide better value to the customer and reduce waste.

Major owners, designers, and contractors have commissioned LCI to assist in the implementation of Lean Construction in their firms. It has not been uncommon for these efforts to reduce total cost and duration of a project by an astounding thirty percent!

Lean Construction planning and control techniques reduce waste by improving work flow reliability. The starting point is improving the reliability of assignments at the crew level. This is in contrast to current management approaches that rely on project level plans to manage contracts instead of managing work, and contract commodity-based control systems that do not measure planning systems performance. Lacking a predictable work flow, design squads, field crews, or similar production units must adopt a strategy of flexibility to keep busy. Unfortunately, flexibility applied at one work station demands flexibility downstream. This current practice injects uncertainty in the flow of work, rendering it impossible to plan!

Lean Construction starts by stabilizing the work flow through reliable planning which shields the crew from that uncertainty management cannot control. Injecting certainty into the flow of work by shielding improves performance of the immediate production unit up to 30% or more while stabilizing flow downstream. Predictable flow at any point in the supply and assembly chain then makes it possible to reduce inflow variation upstream and redesign operations downstream. These techniques have been proven in both design and construction, on small and larger design-build or competitively bid as well as very large fast-track projects, and by independent specialty contractors.

Using this workbook you will gain a new perspective on what it means to plan a job. You will develop a better understanding of the impact variability has on downstream performance, and you will learn how the Last Planner can shield work groups from uncertainty and thereby improve performance of the production unit as well as overall system throughput.

Glenn Ballard, Greg Howell, Iris Tommelein, and Todd Zabelle

PURPOSE AND SCOPE OF THE LAST PLANNER WORKBOOK

This workbook introduces the Last Planner, a system of lean construction principles that help increase the reliability of a planning system and thereby significantly improve performance.

The Last Planner system involves action at many different levels starting with the master schedule covering an entire project, followed by a detailed phase schedule emerging from collaborative planning; the lookahead schedule comes next with constraints analysis and making assignments ready. The last step is developing the weekly work plan and measuring percent plan complete.

The Last Planner methodology explicitly defines criteria for making quality assignments. The Last Planner considers those quality criteria *in advance* of committing production units to doing work in order to shield these units from uncertainty and variability. The plan's success at reliably forecasting what work will get accomplished by the end of the week is measured in terms of Percent Plan Complete or PPC. Root causes for plan failure are then investigated at the end of each week so they may be avoided in the future.

Increasing PPC leads to increased performance, not only of the production unit that executes the Weekly Work Plan, but also of production units downstream as they can better plan when work is reliably released to them. Implementation of the Last Planner therefore results in more reliable flow and higher throughput of the production system.

Example problems provide the reader with hands-on experience in weekly work planning and calculating plan reliability, then identifying root causes and learning. Sample forms for constraints analysis and weekly work planning are included in the back of the book. Readers are encouraged to photocopy them and use them in their practice.

Please keep us posted on your PPC measurements and what you learn from them.

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LAST PLANNER SYSTEM FOR PRODUCTION CONTROL

The Last Planner system, based on lean construction principles, aims at increasing the reliability of planning and thereby improves performance. Increasing plan reliability is done by taking action at several levels in the planning system.

The Last Planner planning cycle (shown in figure 1) comprises: the master schedule covering an entire project, the detailed phase schedule emerging from collaborative planning, the look-ahead plan with constraints analysis and the weekly work plan with measured percent plan complete.

Front end planning begins with the master schedule which initiates strategic planning, identifies major milestone dates and incorporates critical path method (CPM) logic to determine overall project duration. Phase scheduling generates a detailed schedule that evolves during the project by magnifying the master schedule into more detailed project components. Using collaborative planning combined with reverse phase scheduling activity durations, handoffs and relationships are further evaluated often resulting in modifications to the CPM logic.

Production planning begins with the magnification of detailed activities on the phase schedule into the lookahead plan. The lookahead plan is a list of activities that need to be worked on over the upcoming six weeks. The plan is updated weekly where constraints that threaten reliable workflow are studied. Identifying responsibilities and making assignments ready follows by analyzing resource management information.

The Weekly Work Plan is the most detailed plan in the system. 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 week, assignments are reviewed for completeness in order to measure the reliability of the planning system. Analyzing reasons for plan failures and acting on these reasons is the basis of learning.

Figure 2 shows the different actions dictated taken during the Last Planner planning cycle to establish reliable work flow.

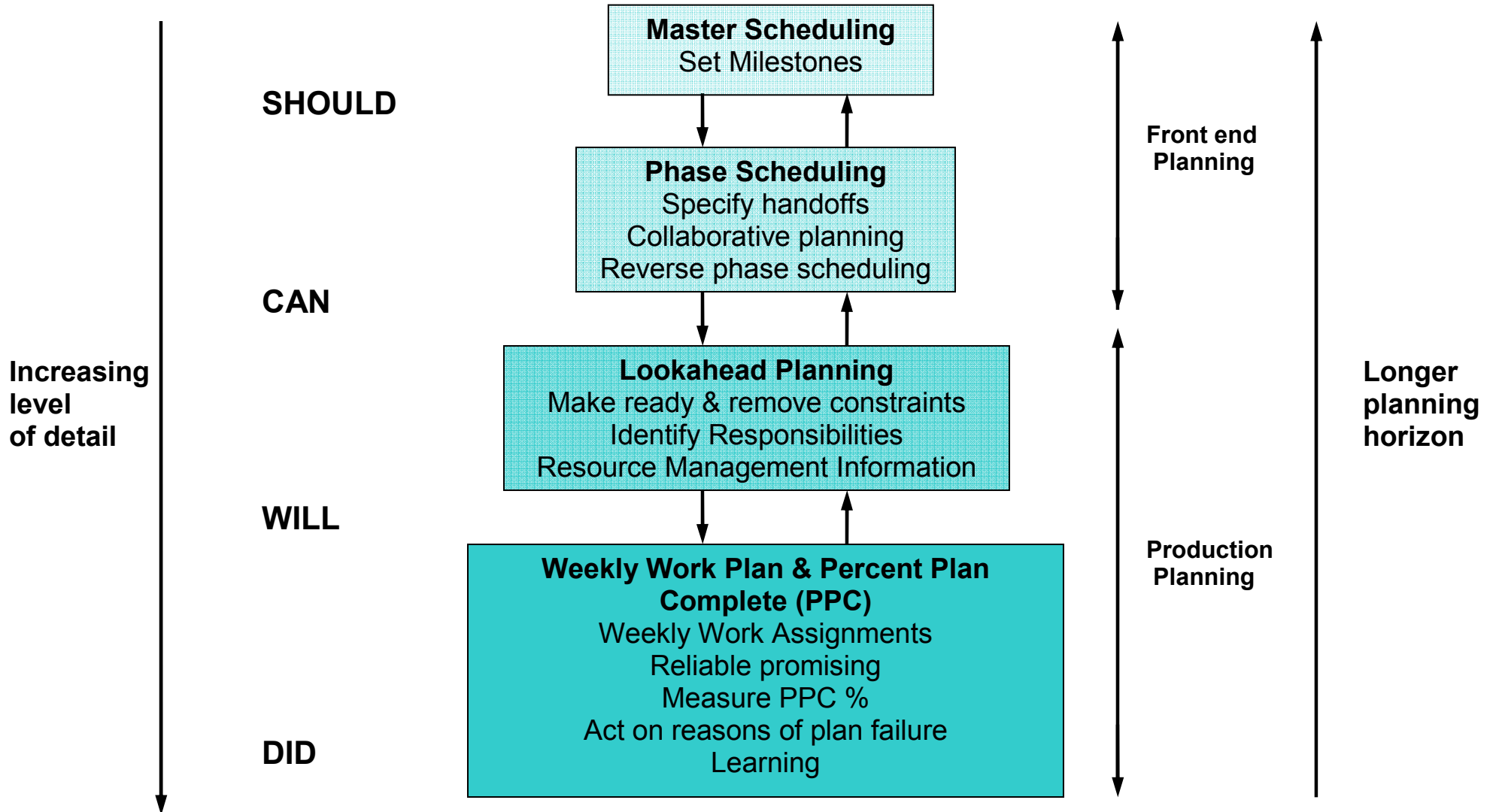


Figure 1: The Last Planner Planning Cycle

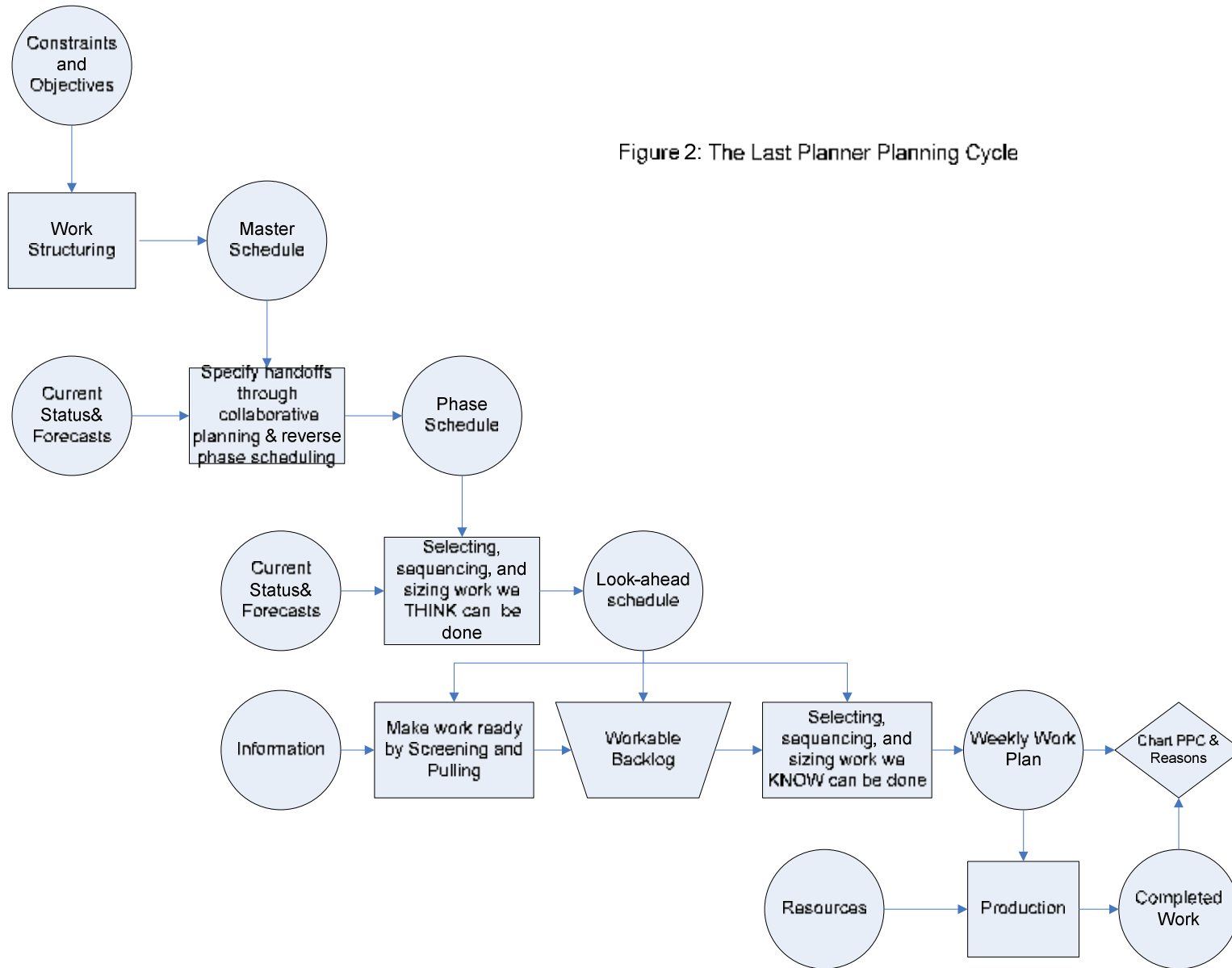


Figure 2: The Last Planner Planning Cycle

WORK STRUCTURING

In the Lean Project Delivery System, the term “work structuring” is used to indicate the various activities involved in specifying how work is to be done, from structuring the project and supply chains organizationally all the way to detailed methods for fabrication and assembly, and including configurations of supply systems.

Work structuring is production system design comprising development of operation and process design in alignment with: product design, structure of supply chains, allocation of resources, and design-for-assembly efforts with the goal of making work flow more reliable and quick while delivering value to the customer. A key tenet of lean construction is to integrate the design of product and process.

Work structuring extends in scope from an entire production system down to the operations performed on materials and information within the system. Work structuring differs from work breakdown structure which was traditionally used by planners to decompose a project into work packages to create a framework for project planning, scheduling, and controls in the functions it performs and the questions it answers.

Work structuring answers the following questions:

- (1) In what units will work be assigned to groups of workers?
- (2) How will work be sequenced?
- (3) How will work be released from one group of workers to the next?
- (4) Will consecutive groups of workers execute work in a continuous flow process or will their work be decoupled?
- (5) Where will decoupling buffers be needed and how should they be sized?
- (6) When will different units of work be done? (Howell et al. 1993 and Tsao et al. 2004).

Figure 3 shows work structuring as ongoing dynamic process spanning the whole project life cycle from designing the overall system at the beginning of a project to guiding design and execution throughout the rest of the project.

Some of the products of work structuring are:

- Project execution strategies including global sequencing where sequence of execution is delineated (building A, then D, then B etc; or build floors of hi-rise in quadrants going counterclockwise starting at the north side).
- Project organizational and contractual structure
- Configuration of supply chains
- Rough-Cut operations design (decision to cast-in-place versus precast, or use a tower crane versus rolling stock)
- Detailed operations design (how to form-rebar-pour basement walls)
- Master schedules
- Phase schedules

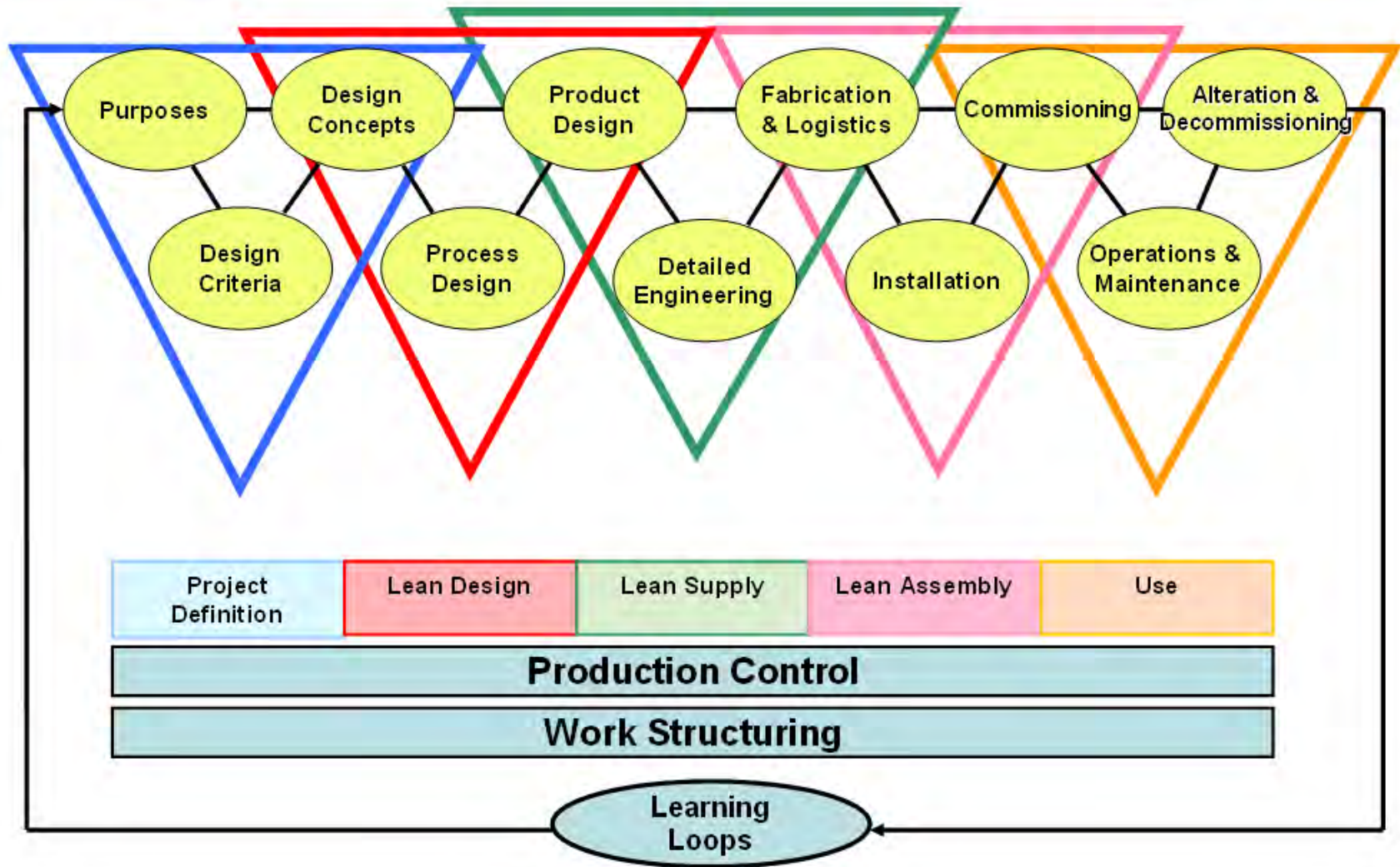


Figure 3: Work structuring as a part of Lean Project Delivery System.

MASTER SCHEDULE

The master schedule is produced during front end planning and represents the milestone level of project planning specifying the timing of the various phases a project goes through. This schedule is broken down mainly by function, area, or product. It covers the entire project duration and presents activities at a coarse level with a long planning horizon. As a product of work structuring, the master schedule reflects important milestones dictated by project constraints and objectives as delineated in Figure 4. An excerpt of a actual Master schedule is shown in Figure 5.

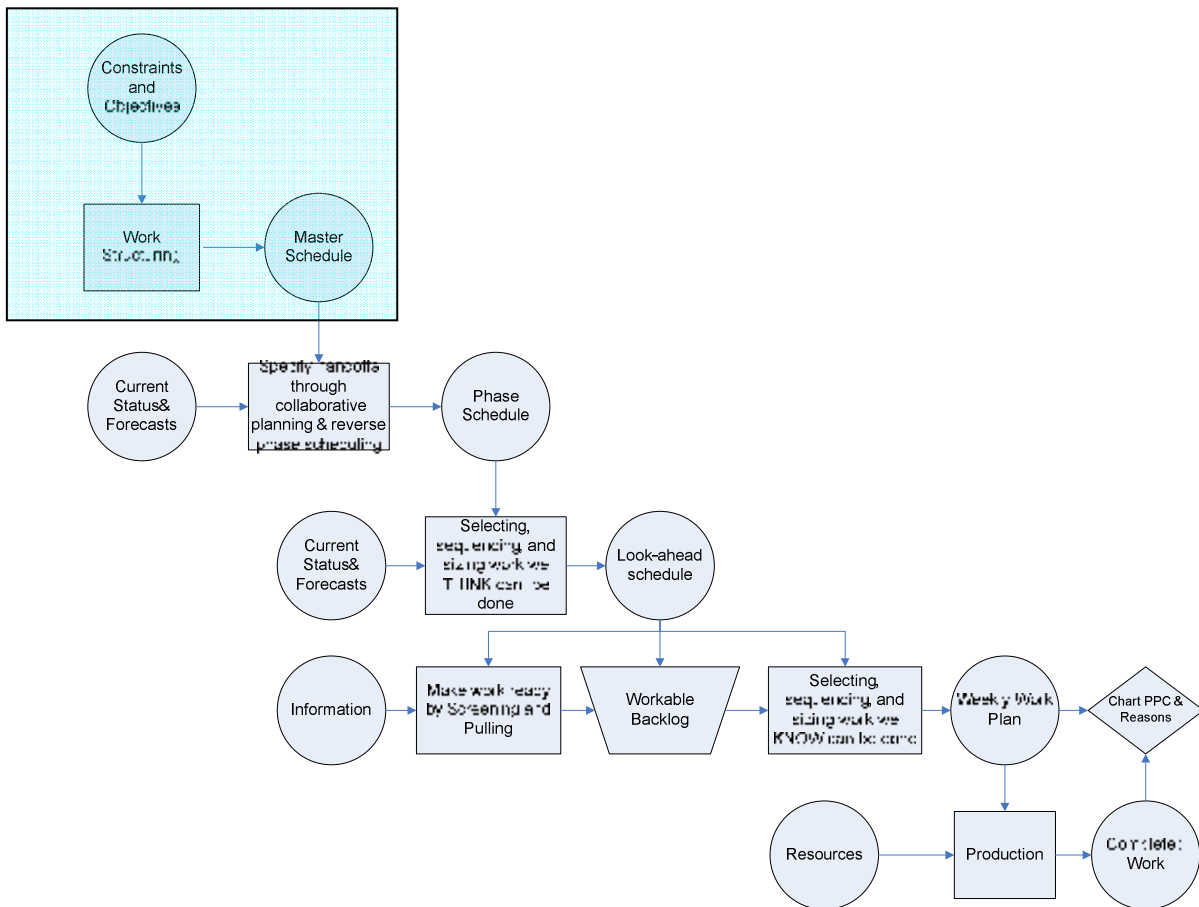


Figure 4: Master Schedule fragment of Last Planner System.

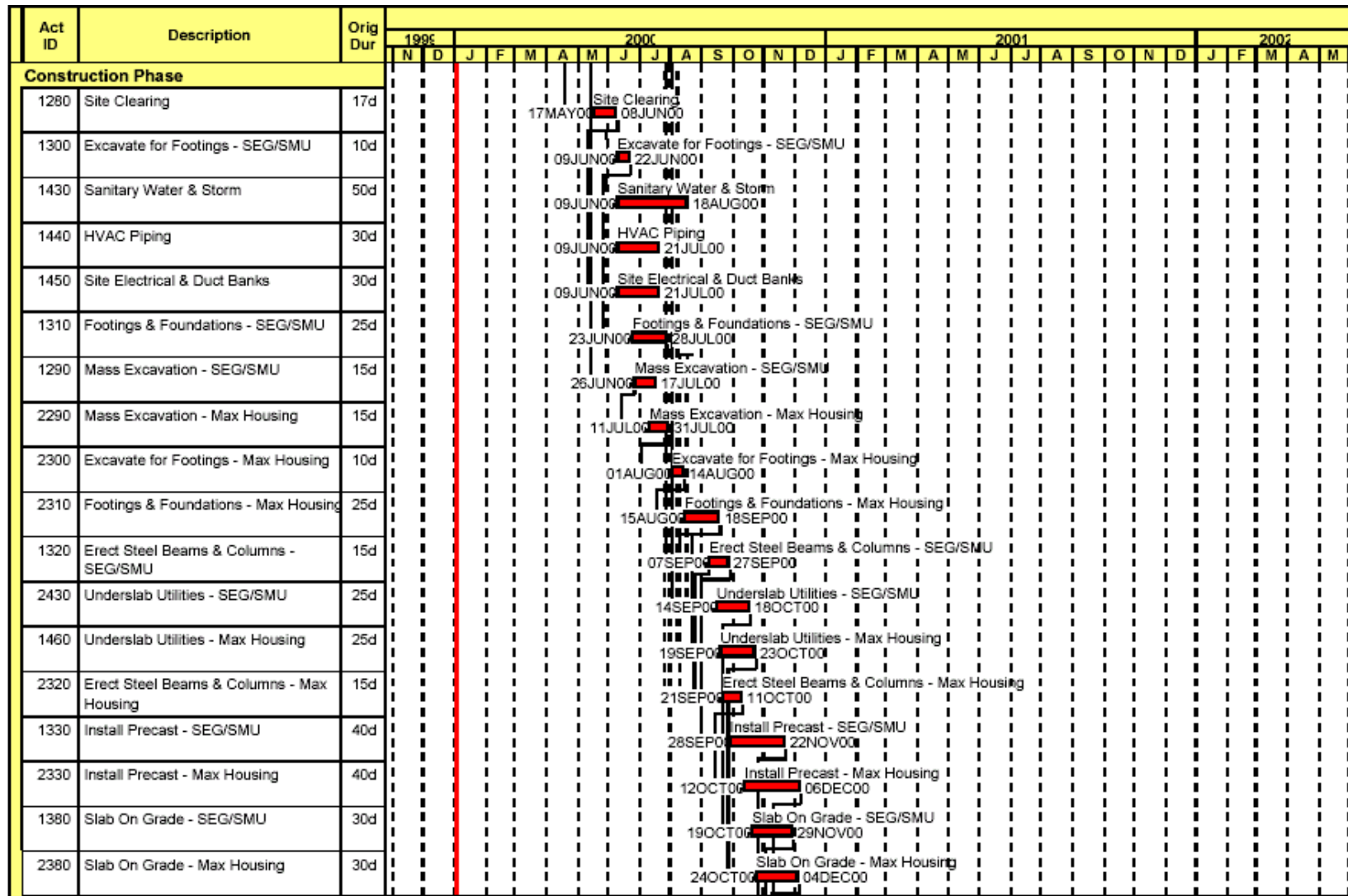


Figure 5: A sample Master Schedule.

PHASE SCHEDULING

Phase scheduling links work structuring and production control providing goals to which to steer. Without it, there is no assurance that the right work is being made ready and executed at the right time to achieve project objectives. The integration and coordination of various specialists' operations is the purpose of the phase schedule. The level of detail in the phase schedule is determined by the requirement that the phase schedule specify the handoffs between the specialists involved in doing the work in that phase. These handoffs then become goals to be achieved through production control.

The concept of "phase" is proposed to occupy the level of the work breakdown structure that comes after the subdivisions of the product to be built. The work to be done by specialists involved in a phase is then structured by further subdivision of product by specification of process.

When projects are large and complex, a single master schedule may represent activities only in broad terms and a single lookahead to cover all exploded tasks may become unwieldy. Accordingly, the master schedule may be broken up into phase schedules as shown in figure 6, with master schedule activities being exploded into sets of tasks to cover the entire activity duration, each one grouping work that need to be performed in close spatial as well as temporal proximity of one another.

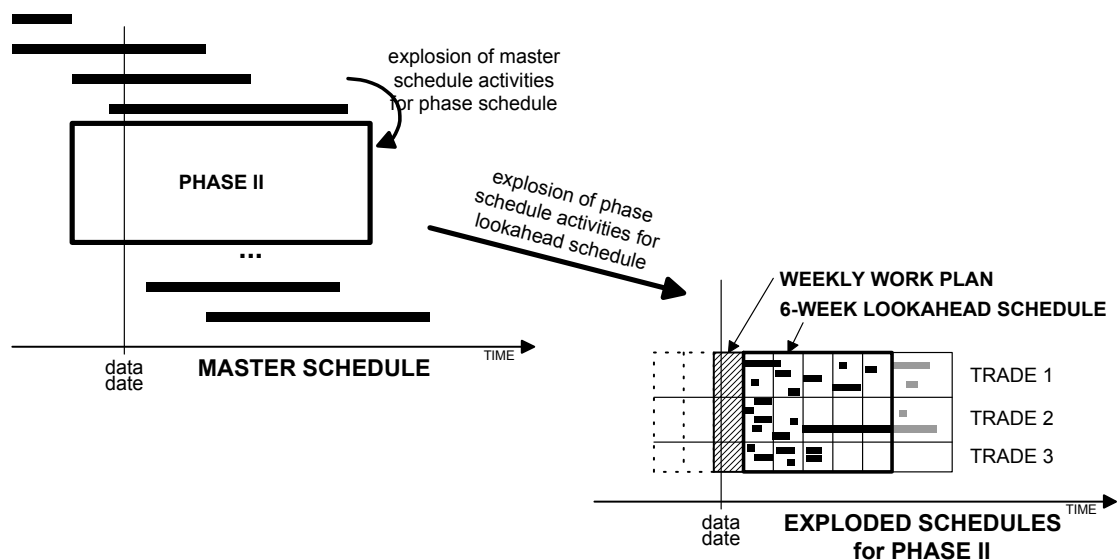


Figure 6: Exploding Master schedule into a Phase schedule

LCI recommends using pull techniques and team planning to develop schedules for each phase of work, from design through turnover. The phase schedules thus produced are based on targets and milestones from the master project schedule and provide a basis for look-ahead planning as shown in Figure 7.

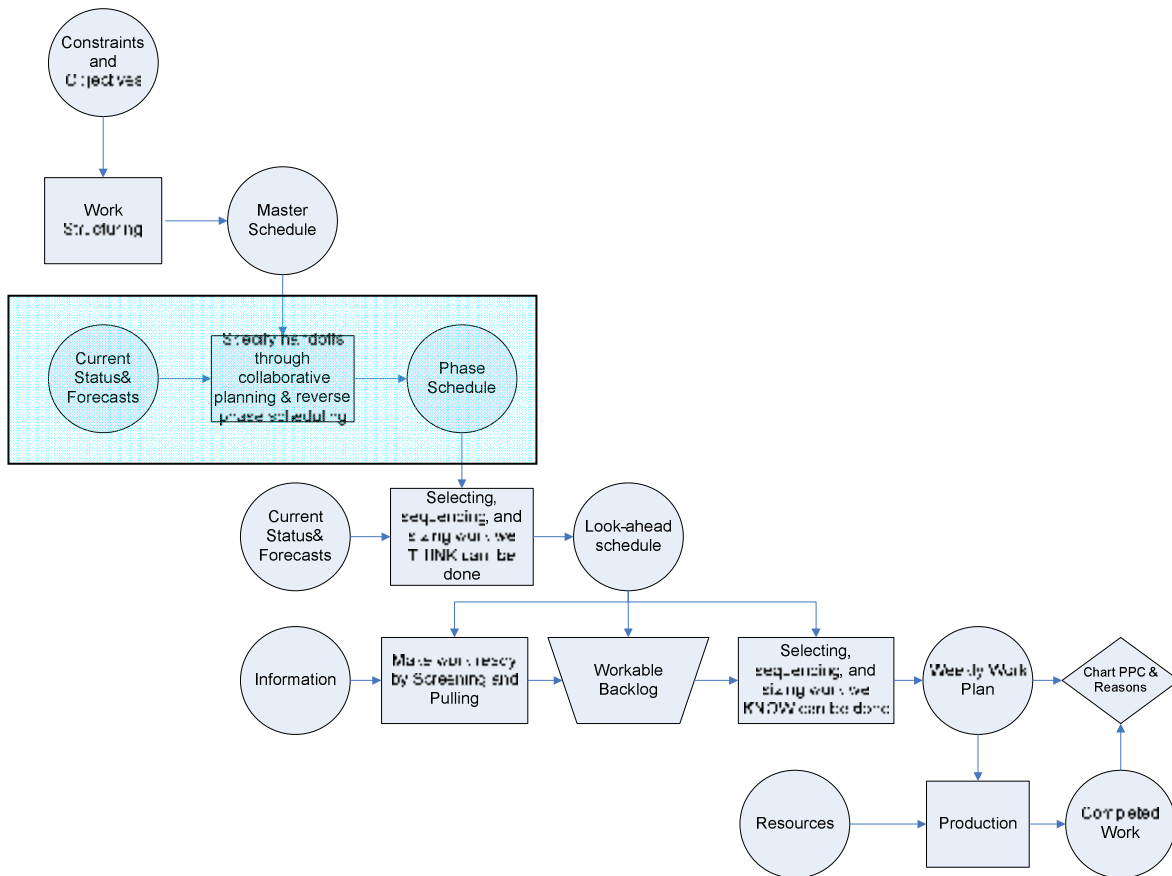


Figure 7: Phase scheduling fragment of Last Planner System

A pull technique is based on working from a target completion date backwards (some times called “Reverse Phase Scheduling”), which causes tasks to be defined and sequenced so that their completion releases work; i.e., achieves a handoff. A rule of “pulling” is to only do work that releases work- requested by someone else. Following that rule reduces the waste of overproduction. Working backwards from a target completion date eliminates work that has customarily been done but doesn’t add value.

Team planning involves representatives of all organizations that do work within the phase. Typically, team members write on sheets of paper brief descriptions of work they

must perform in order to release work to others or work that must be completed by others to release work to them. They tape or stick those sheets on a wall in their expected sequence of performance. Usually, planning breaks out in the room as people begin developing new methods and negotiating sequence and batch size when they see the results of their activities on others.

The first step of formalizing the planning and the phase schedule is to develop a logic network by moving and adjusting the sheets. The next step is to determine durations and see if there is any time left between the calculated start date and the possible start date. It is critical that durations not be padded to allow for variability in performing the work. Designers and builder specialists can provide unpadded durations for their assigned tasks, confident that uncertainties will be buffered and that unfair burdens will be rectified. We first want to produce an 'ideal' schedule based on average duration estimates.

The team is then invited to reexamine the schedule for logic and intensity (application of resources and methods) in order to generate a bigger gap. Then they decide how to spend that time: 1) assign to the most uncertain and potentially variable task durations, 2) delay the start in order to invest more time in prior work or to allow the latest information to emerge, or 3) accelerate the phase completion date. If the gap cannot be made sufficiently positive to absorb variability, the phase completion date must slip out, and attention turns to making up that time in later phases. The key point is to deliberately and publicly generate, quantify, and allocate schedule contingency.

PURPOSE OF PHASE SCHEDULING

The purpose of phase scheduling is to produce a plan for completing a phase of work that maximizes value generation and one that everyone involved understands and supports; to produce a plan from which scheduled activities are drawn into the look-ahead process to be exploded into operational detail and made ready for assignment in weekly work plans.

Participants in the phase scheduling process are representatives of those with work to do in the phase. For example, a team working to schedule a construction phase would typically involve the general contractor and subcontractors, and perhaps stakeholders such as designers, client, and regulatory agencies. Participants should bring relevant schedules and drawings including the master schedule and perhaps even the contract.

Process

1. Define the work to be included in the phase; e.g., foundations building skin, etc.
2. Determine the completion date for the phase, plus any major interim releases from prior phases or to subsequent phases.
3. Using team planning and sticky backed cards on a wall, develop the network of activities required to complete the phase, working backwards from the completion date, and incorporating any interim milestones.
4. Apply durations to each activity, with no contingency or padding in the duration estimates.
5. Reexamine logic to try to shorten the duration.
6. Determine the earliest practical start date for the phase.
7. If there is time left over after comparing the time between start and completion with the duration of the activities on the wall, decide what activities to buffer or pad with additional time.
 - a. Which activity durations are most fragile?
 - b. Rank order the fragile activities by the degree of uncertainty.
 - c. Allocate available time to the fragile activities in rank order
8. Note: this is contingency you intend to spend, unlike budget contingency
9. Is the team comfortable that the available buffers are sufficient to assure completion within the milestone(s)? If not, either explain or shift milestones as needed and possible.
10. If there is excess time available beyond that needed for buffering, decide whether to accelerate the schedule or use the excess to increase the probability of on-time completion.
11. Reserve unallocated time in a general contingency buffer for the phase.

In summary, phase scheduling is proposed as a technique for developing a plan for completing work within a phase of a master schedule. It can be used as one means for developing master schedules themselves. The plans are produced using a team approach, backward pass and public allocation of schedule contingency to absorb or buffer remaining variability. The handoffs between the various specialists involved in the phase become the focal points for control through the Last Planner system. Failure to specify these handoffs leaves Last Planner without clear objectives.

LOOKAHEAD PLANNING

The lookahead planning process is the middle level in the planning system hierarchy, following front end planning which results in the master schedule and phase schedule. It precedes commitment planning which results in the weekly work plan as shown in figure 8.

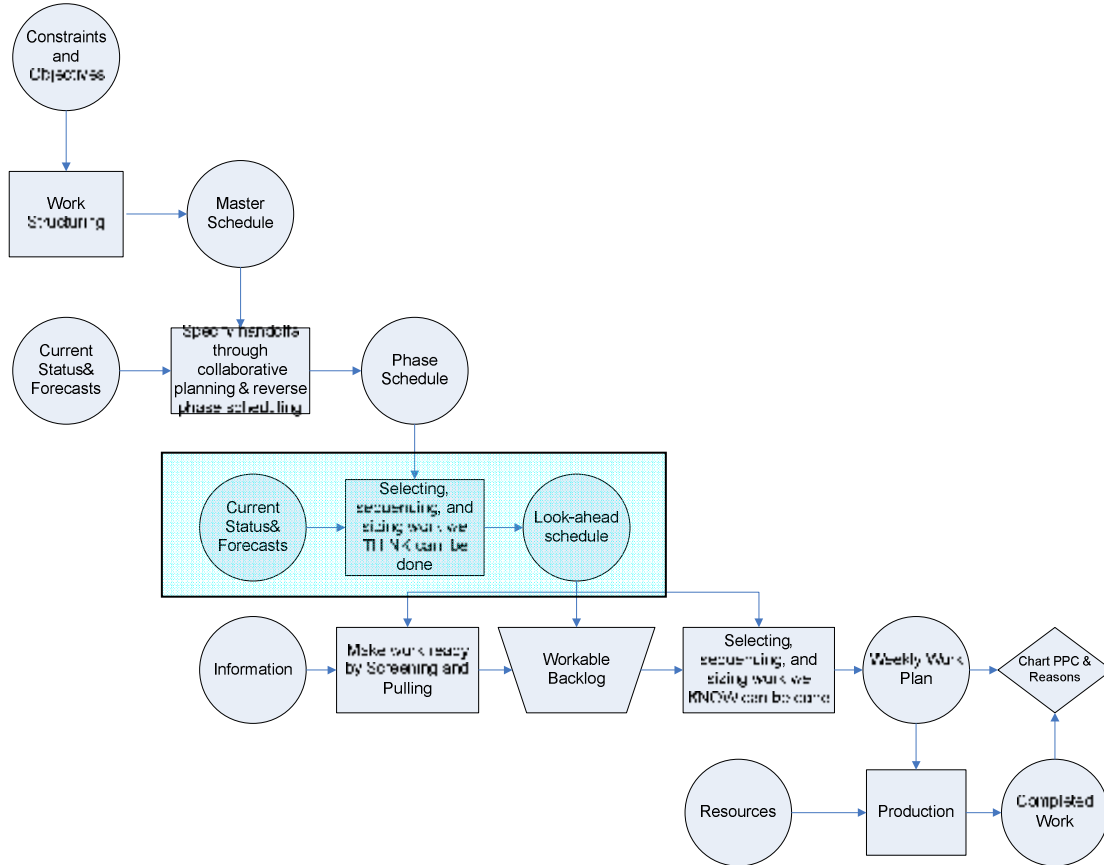


Figure 8: Lookahead schedule fragment of Last Planner System.

Front end planning produces the project budget and schedule. It provides a coordination map that pushes completion and deliveries onto a project. Lookahead planning details and adjust budgets and schedules, pulling resources into play and screening activities for which resources are likely not to be available. Lookahead planning is dedicated to controlling the flow of work through the production system. **Lookahead planning streamlines the work flow for the Last Planner.** Commitment planning involves committing to what will be done, after evaluating SHOULD against CAN based on actual receipt of resources and completion of prerequisites.

What time frame does the lookahead cover?

As mentioned, the **master schedule** covers all activities in the entire project, from start to finish. By contrast, the lookahead typically spans only a 5 to 6 weeks out into the future relative to the planning date, because uncertainty about what is to come later renders planning in greater detail meaningless. Both the Lookahead and the Weekly Work Plan increasingly **explode** tasks to be performed, taking into account actual circumstances. The Lookahead and in turn the Weekly Work Plan cover shorter time spans into the immediate future but reflect higher degrees of confidence that work will be executable.

How far out into the future the lookahead spans, is a function of the nature of the work to be performed and the responsiveness of the **suppliers**, that is, those supplying **input** (including prerequisites, resources, and directives) to the various activities. Some activities have a long **supplier lead time**, so it takes a long time from the moment a request for delivery of an input is made to the moment of receipt of that delivery. Lead times must be identified during front end planning for each activity in the master schedule.

Some activities have extremely long lead times. The design, prototyping, testing, and fabrication of a curtain wall system may take six months or more. Specifying and then custom fabricating windows or air handling units easily takes several months. Depending on the specifics of what is needed, there may also be a large variation and significant uncertainty in delivery time. Those involved on a project must be aware of these lead times so that they can act in due time without jeopardizing downstream process execution.

Quite a few activities have lead times of only a few days or weeks, however. Once ordered, they can be delivered according to a reliable schedule (delivery specified, say, plus or minus a day). Ordering and obtaining a reasonable quantity of standard lumber, drywall, or commodity concrete fall into this category. These materials may be ordered a very long time in advance of their scheduled use depending on market pricing, the need to reserve plant capacity, and the delivery situation, but more often than not they are procured only a few days or weeks ahead of their use.

The time span covered by the lookahead schedule is determined by how long ahead of time forecasts for readying work (such as computing the daily-needed delivery quantities and ordering) can be made reliably. Typically lookahead windows extend from 3 to 12 weeks into the future. Once an activity has entered into the lookahead, it is the planner's task to

make that activity ready for execution by the scheduled time. If a lead time on an activity exceeds the lookahead span, then the planner cannot be certain that activity will be ready by

the scheduled start date. The Last Planner therefore will *NOT* admit this activity into the lookahead.

The lookahead window must be larger than the window of reliability that defines how far in advance future work completions are accurately forecast.

This unwillingness of the planner to allow certain activities to advance into the lookahead contrasts starkly with current practice where lookaheads have set time spans and provide mere drop-outs from the master schedule.

Which activities get posted on the lookahead?

The front end planning process, resulting in master **schedule** and **phase schedule**, covers all activities in the entire project. By contrast, the lookahead includes only activities that meet certain considerations. The **lookahead window** determines how far ahead of the scheduled start date activities in the master schedule are considered for entry into the lookahead. In addition, entry into the lookahead is governed by:

1. **Explosion:** detailing master schedule activities by means of the activity definition model. A greater amount of detail is needed during lookahead planning regarding the activity's inputs and outputs so that the planner can screen the constraints on the activity and ascertain that the activity can be made ready by its scheduled start date.
2. **Screening:** determining the status of tasks in the lookahead window relative to their constraints, then choosing to advance them into the lookahead schedule or retard tasks on the master schedule based on their constraint status and the probability of removing constraints prior to the activity's scheduled start. A following section of this workbook presents quality criteria for the lookahead planner to use in screening activities.
3. **Make ready:** taking actions needed to remove constraints from activities to make them sound so they will be ready at the scheduled time for assignment in a weekly work plan by the Last Planner. This can be done for instance using pulling and expediting as is explained later in this workbook.

What does a lookahead schedule look like?

Lookahead schedules may be presented in table or bar chart format. An engineering lookahead in bar chart format is shown below:

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

QUALITY CRITERIA

Shielding in Weekly Work Planning

The Last Planner uses information about resource availability to move into the Weekly Work Plan selected activities that satisfy certain criteria and that are shown in the first week of the Lookahead Schedule. Choosing what work WILL be performed in the next week from what CAN be performed is termed making **quality assignments**. Only quality assignments may be put on a Weekly Work Plan as this will **shield** the production crew from uncertainties in workflow and thereby increase plan reliability.

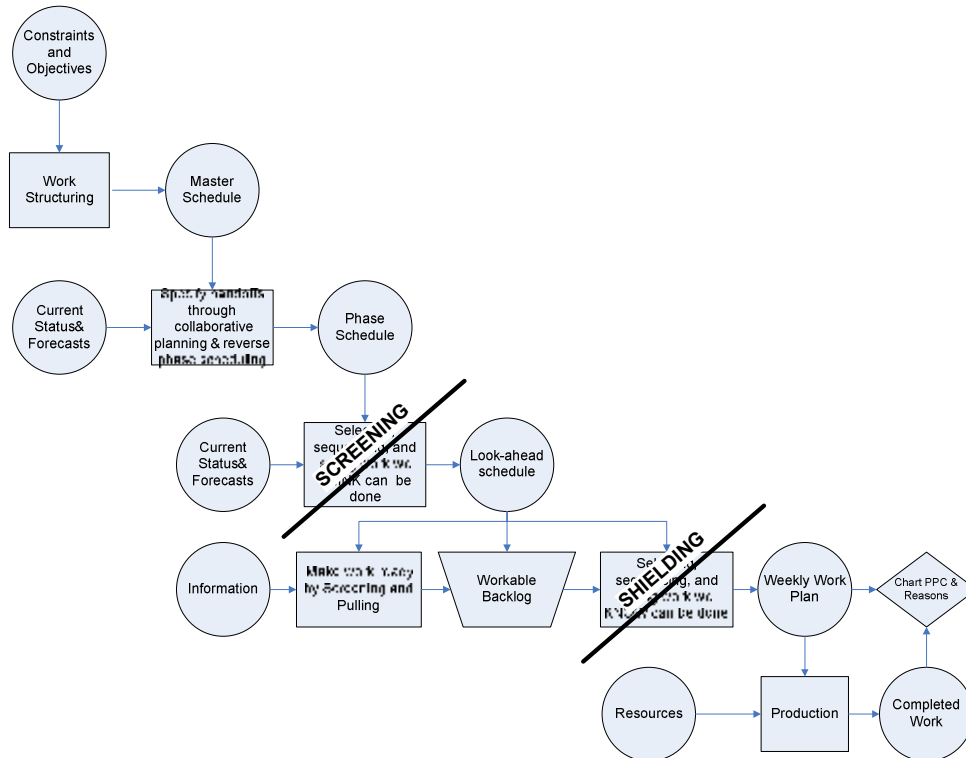
Weekly Work Plans are effective when assignments meet five specific quality criteria, namely:

Definition: Are assignments specific enough that the right type and amount of information or materials can be collected, work can be coordinated with other disciplines or trades, and it is possible to tell at the end of the week if the assignment has been completed?

4. **Soundness:** Are all assignments workable? Do you understand what is required? Do you have what you need from others, are all materials on hand; is design complete; is prerequisite work complete, etc.? Note that some make-ready work will remain for to be done during the week, e.g., meeting with other designers or fabricators, coordinating with trades working in the same area, moving materials to the point of installation, etc. Nonetheless, the intent is to do whatever can be done to get the work ready before the week in which it is to be done.
5. **Sequence:** Are assignments selected from those that are sound in priority order and in order of workability? Will doing these assignments release work needed by someone else? Are additional lower-priority assignments identified as workable backlog, that is, are additional quality tasks available in case assignments fail or productivity exceeds expectations?
6. **Size:** Are assignments sized to the productive capability of each individual or group while still being achievable within the plan period?

- Learning:** Are assignments that are not completed within the week tracked, reasons for deviation identified, and action taken?

Having a plan that meets these quality criteria does not guarantee success. A plan could always fail in execution. However, the purpose of the Last Planner is to help minimize plan quality failures so that unnecessary execution failures can be avoided.



Screening in Lookahead Planning

Activities that do not meet the criteria regarding definition and soundness have to be screened and made ready first. In order to ease sequencing and sizing when making assignments, activities must be balanced if possible. These are done in the lookahead process.

SCREENING

Screening is determining the status of tasks in the lookahead window for readiness relative to their constraints, then choosing to advance them into the lookahead schedule or retard tasks on the master schedule based on their constraint status and the probability of removing constraints prior to the task's scheduled start. Screening during lookahead is less restrictive than shielding during weekly work planning is: screening does not prevent a task with outstanding constraints from moving forward as long as enough time remains to get those constraints removed. Screening is first done when activities are considered for entry into the lookahead. It is then repeated in each planning cycle, when the planner updates the lookahead and advances it to the next week.

The probability of the planner being able to remove constraints on tasks in the lookahead, prior to those tasks' scheduled start, is a function of the lead times needed to get deliverables from suppliers and also of the make-ready actions taken by the planner.

CONSTRAINTS ANALYSIS

A **constraint** is anything that stands in the way of a task being executable or sound. Constraints concern directives, prerequisites, or resources. Typical constraints on design tasks are inputs from others, clarity of criteria for what is to be produced or provided, approvals or releases, and designer or engineering resources. Typical constraints on construction tasks are the completion of design or prerequisite work; availability of materials, information, directives, and labor or equipment resources. Constraints will be different depending on whether the planner is coordinating the entire production process or only that part in which they specialize.

The Constraints Analysis Form depicts a table with rows listing potential assignments and columns listing outstanding constraints if there are any. Each constraint category provides an indication of who may be involved in removing a constraint. These constraints remain to be resolved for the corresponding assignment to be considered sound (one quality criterion). The Constraints Analysis Form, like the one shown, aids in systematically identifying and tracking the status of constraints on assignments.

MAKE-READY

The planner can remove constraints from a task so as to **make** that task **ready** to be assigned. A ready task scheduled in the earliest week of the lookahead will in the weekly planning cycle have to roll over and be assigned the weekly work plan in order to cause minimal schedule disruption.

To make ready is a three step process:

Confirming Lead Time: Removing a constraint starts by finding out who the supplier is of the corresponding input and what the likely supplier lead time is. This lead time should be smaller than the lookahead window or the task should not have been admitted into the lookahead to start with. However, unforeseen events may always crop up, so contacting the supplier is the typical make-ready step. Confirming lead times is part of the screening process and may be repeated during weekly updating of the lookahead schedule.

Pulling: The second make-ready step is to pull, that is, to request the supplier for delivery of input as needed to complete the readiness of the process which it will enter. This pull may cause the supplier to re-sequence their work, which may or may not result in additional cost. An example of pulling are requesting that materials for one area on site be delivered prior to those for another area, because prerequisite work for the first area will be completed sooner.

8. **Expediting:** The third make-ready step is to expedite, that is, to get selective attention from the supplier to remove the constraint. If the anticipated lead time is too large, then allocating additional resources may be needed to shorten them. Examples of expediting are shipping materials by air instead of truck, working overtime, obtaining a building permit for a part of the building when the remaining design is to be completed, or outsourcing to a firm with more sophisticated equipment that therefore can provide the input faster.

BALANCING = MATCHING LOAD AND CAPACITY

As activities enter the lookahead, the planner must ascertain that the required inputs for successful process execution will be available at the scheduled time. Resources may yet remain to be acquired as part of the make-ready work. The questions are: How many resources to make available at any given time? vs. To what extent should available resources be leveled in their use?

The amount of output expected from a production unit (a group of direct production workers that do or share responsibility for similar work, drawing on the same skills and techniques) or individual worker within a given time is termed **load**. Within a weekly work plan, load is what is to be accomplished by a design squad or individual designer, engineer, draftsman, construction craft worker, crew, etc. A quality assignment 'loads' a resource within its capacity. **Capacity** refers to the amount of work a production unit, whether individual or group, can accomplish in a given amount of time. **Balancing** means to match load to capacity of production units.

Balancing is first done during lookahead planning and later during weekly work planning. During lookahead planning, it may not yet be known exactly which production unit will be assigned the work, yet, the planner must be able to tell which kind of production unit is likely to be needed. Even without having the specifics pinned down, the planner thus can assess the availability of those needed resources and their capacity.

Ideally, load and capacity are perfectly matched. Production units continuously have work to do and ready work never gets delayed because of limited capacity of the production unit. In practice, the balancing act is tricky, in part because of variability in loads as well as capacities depending on the nature of the work. This variability is greater in lookahead planning than it is in commitment planning, because more uncertainty remains in the lookahead regarding the actual allocation of resources.

At the commitment planning level, reliability in executing the weekly work plan is achieved by **underloading** the production unit. Assignments are made so that the production unit absorbs less than 100% of its capacity. This also frees up time for the production unit to release time for workers to take part in training or learning, conducting first-run studies, implementing process improvements, or for equipment to be maintained.

At the lookahead planning level, the planner must expedite or delay activities as needed while striving for a balanced work flow, a so-called **continuous flow process** (CFP). A CFP is a type of production line through which work is advanced from one production unit to the next on a first-in-first-out basis. The idea is to approximately balance processing rates of the different production units lined up in a sequence in the CFP so that all can work nearly uninterruptedly while only a modest amount of work-in-progress (WIP) in-between units is allowed to build up. The objective of achieving continuous flow is maximizing the throughput of the system while minimizing resource idle time and WIP. Operations that are logically performed in sequence are identified as processes to be performed as CFDs. A process is then isolated from others by means of decoupling buffers at its extremities.

In streamlining the work flow for the last planner, the lookahead planner may want to make ready slightly more work than the production unit will be assigned to perform. Some lookahead activities may yet fall through because constraints cannot get resolved in due time. The true capacity of the production unit that will do the work also remains unknown at this time and it is affected by how the way the work method gets designed, e.g., during a first run study in the lookahead time window. Finally, a production unit will always want to have some **workable backlog** on their weekly work plan. This workable backlog consists of non-priority items that nonetheless have been made ready. Workable backlog is not assigned to the production unit but rather is made available should any of their assigned tasks fall through or be completed sooner than expected.

FIRST RUN STUDIES

Construction operations are the ways crews use what they have to do work. Work methods appear simple enough when presented in the estimate, but that design is seldom detailed or explicit at the step or sub-cycle level. The design of an operation may be specified in front-end planning, but more design work will remain to be done in the engineering phase and within the look-ahead process when the work package is released to the crew.

First run studies must be routine part of planning, conducted preferably three to six weeks prior to the start of a new operation. They include actually performing the operation in as realistic manner as possible, in order to try out and learn how to best perform the work

involved, identify skills and tools available or needed, interaction of the operation with other processes.

First Run Studies speed the evolution of an operation as the movement between stages is not left to chance. The crew and entire production team comes to grips with the details of the operation in planning before mobilizing in the field. Areas of uncertainty can be identified in advance and decisions made on the coping and learning process to be employed.

Often the crew can reduce the time spent in the initial learning phase of the operation by thinking through the details in an open discussion aided by simple graphics. The idea of interaction can be added to the study by drawing a process chart showing sub cycles and then exploring where intermediate inventories might be placed at the outset without risking quality.

First run operations design are not limited to repetitive operations. Indeed, all operations should be subjected to a design study on each project. Typical studies include process, crew balance and flow charts, as well as space schedules that show how resources move through space and work progresses. It is of utmost importance to measure and understand variability in arrival rates of inputs and processing durations. Construction operations usually begin with a significant uncertainty but first run studies will reduce it.

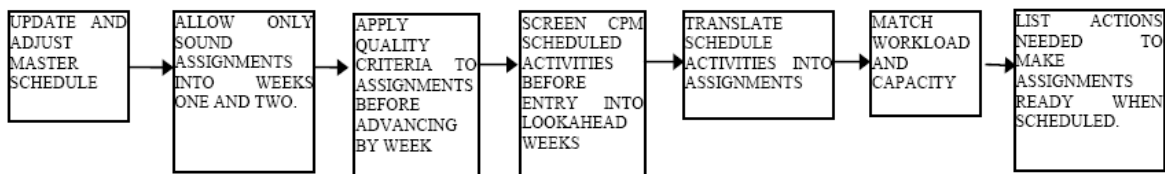
First run studies result in identifying a good way to do work, thereby setting a standard against which all those conducting the work can gauge performance. They are subject to examination and improvement to result in a new and better standard when appropriate. Standards are very important, however, in that they make it easy to delegate responsibility for execution and control to those conducting the work, and they facilitate learning by clearly defining a process that can be mutually agreed upon and critiqued.

An additional benefit of First Run Studies comes with involving safety and quality control in the design of the operation instead of trying to inspect it in later. The documentation prepared in the course of completing a First Run Study provides a way to capture best practices and “remember” them for future projects

LOOKAHEAD TO WEEKLY WORK PLANNING

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. Figure 9 shows lookahead planning as a link between forst end planning and production planning.

These are the steps involved in the process each week:



Step 1: Enter the latest status and forecast information into the project master and phase 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 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.

Step 6: Calculate the earnable man-hours 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. 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.

Step 8: First run studies to be performed for activities starting between week 4 and week6.

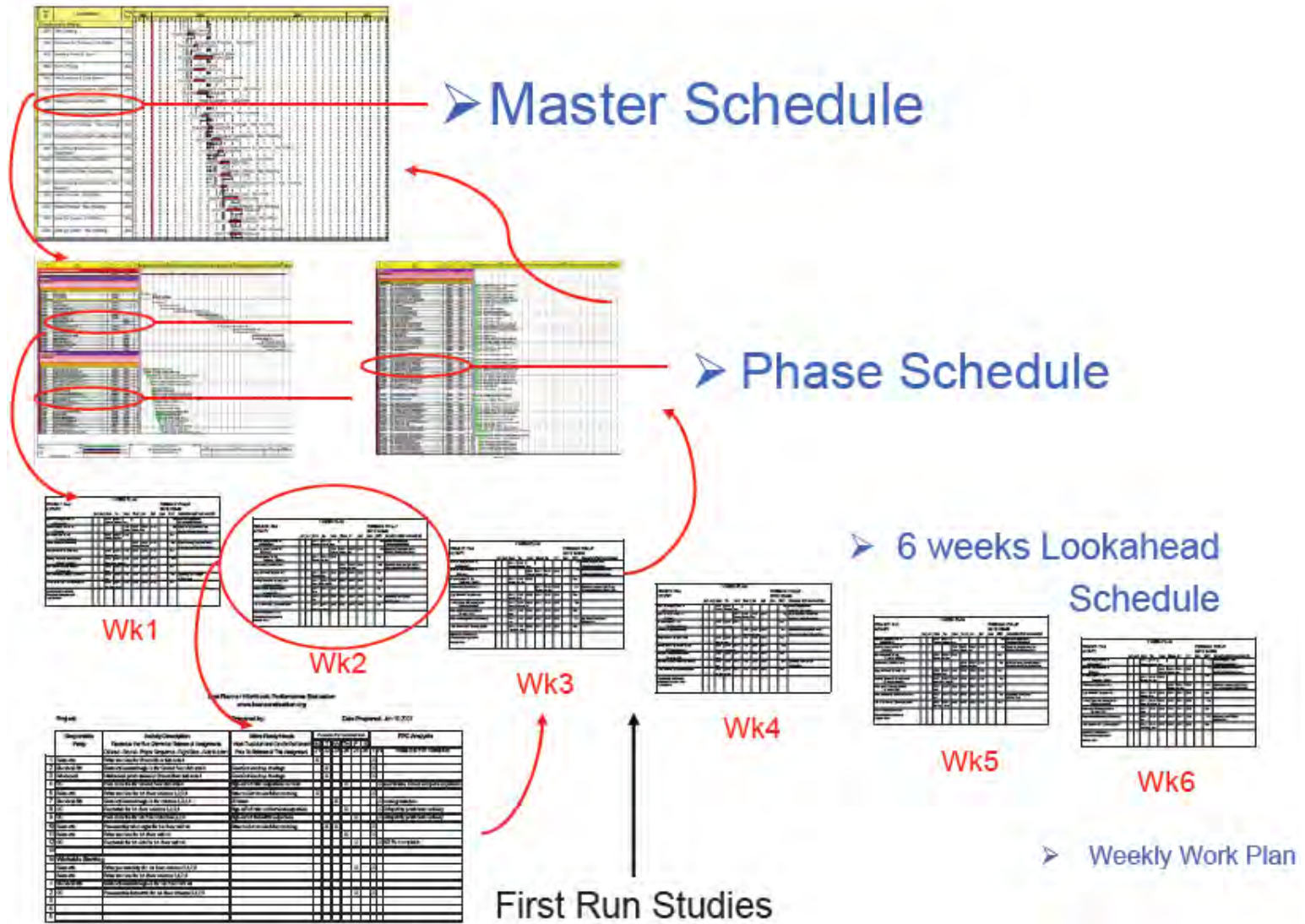
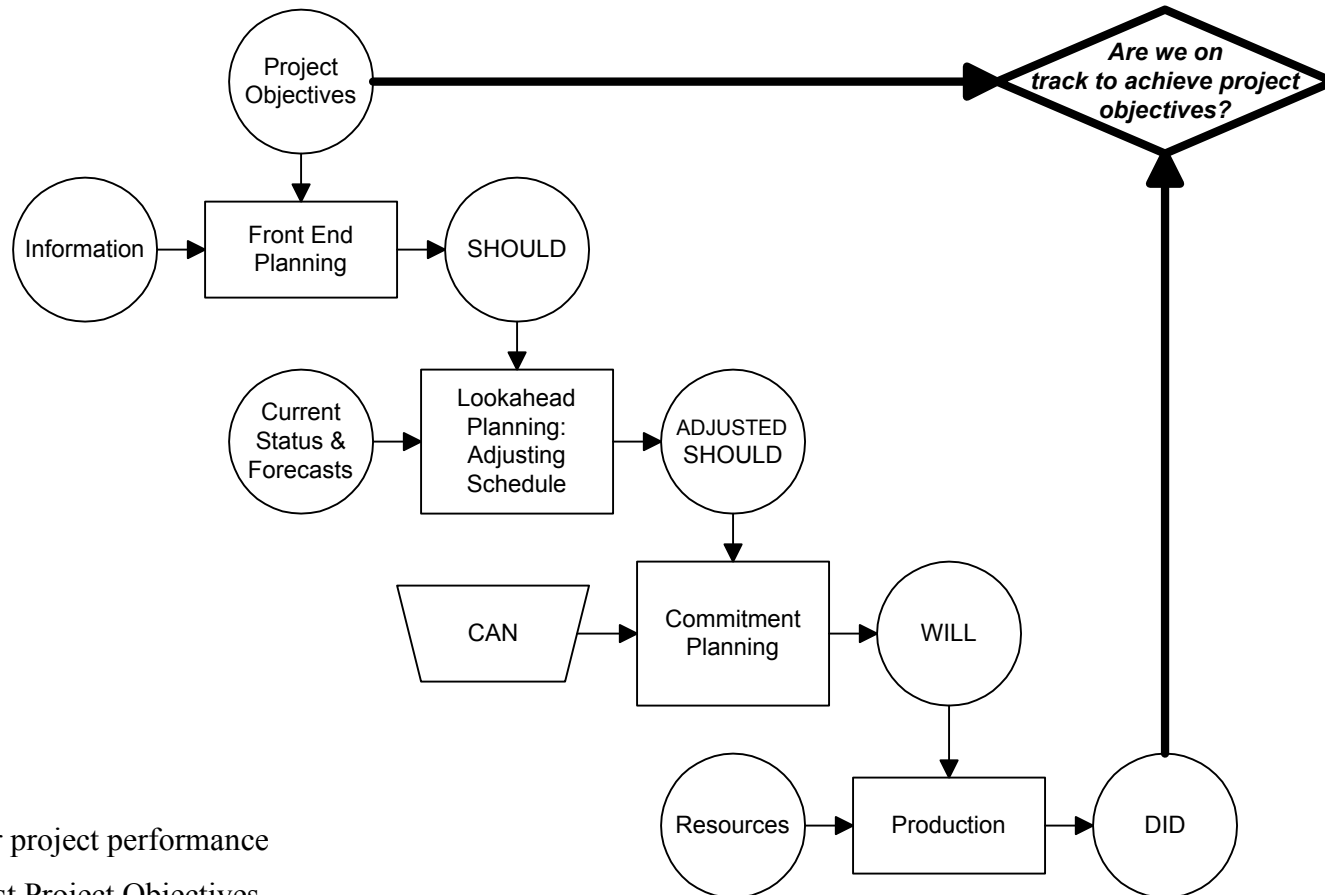


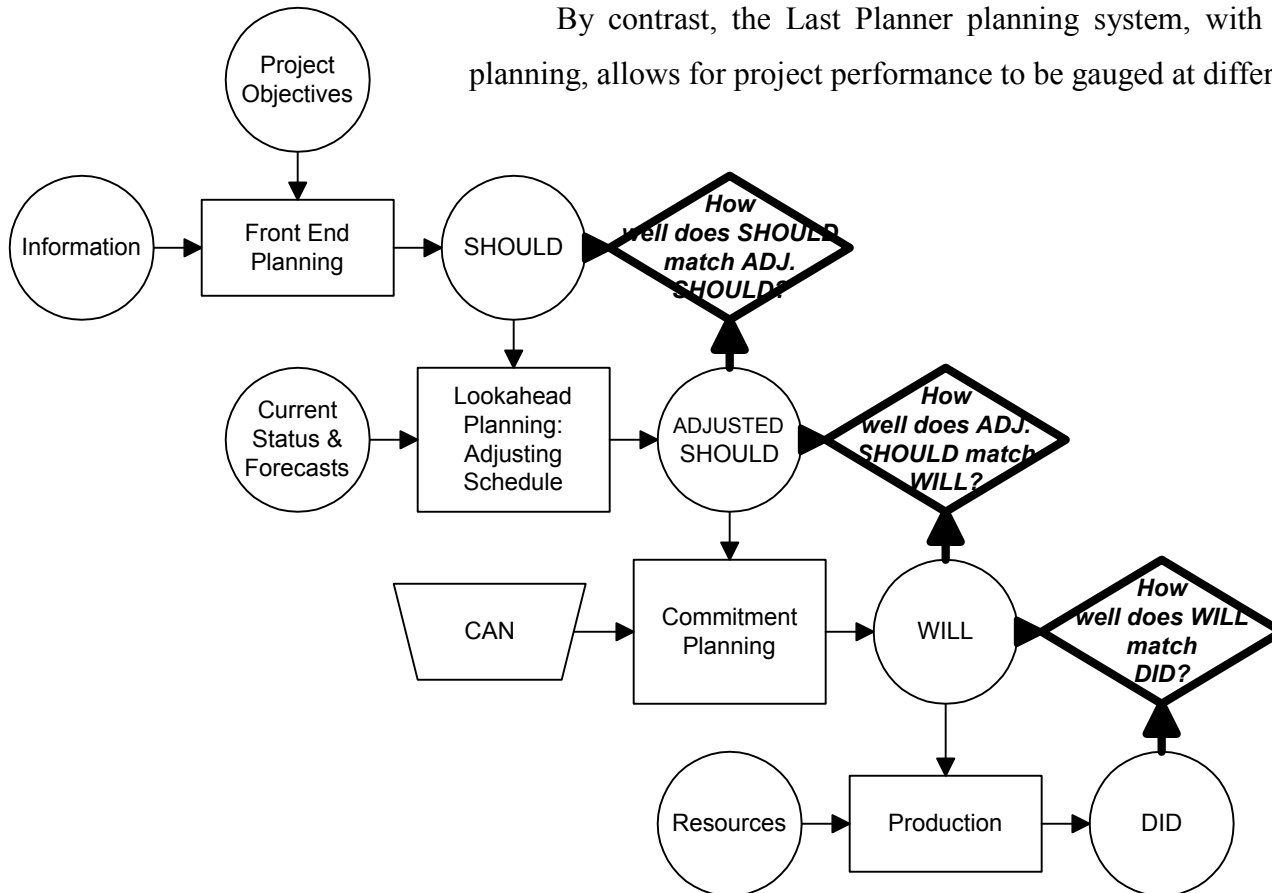
Figure 9: Look ahead schedule as part of the planning cycle.

MEASURES OF PERFORMANCE OF LOOKAHEAD



A traditional measure for project performance is to compare DID against Project Objectives.

By contrast, the Last Planner planning system, with its techniques for lookahead and assignment planning, allows for project performance to be gauged at different levels.



In weekly work planning, the last planner tracks the number of actual completions divided by the number of planned completions. We refer to this performance measure as **percent plan complete, PPC**, or also **PPC1** as it assesses the reliability of planning work that is one week out into the future. In lookahead planning, the Last Planner defines two additional performance measures: **assignments made ready** or **AMR** and **assignments anticipated** or **AA**.

PPC₂

Divide the number of assignments completed in the plan week by the number of assignments listed in the Week Two plan. Answers the question:

How good a predictor of work flow are plans made two weeks in advance?

AMR₂

Divide the number of assignments that appear in both the Week One and Week Two plans by the number planned in Week Two. Answers the question:

What percentage of assignments are being made ready so they can be placed on weekly work plans when scheduled?

AA₂

Divide the number of assignments that appear in both Week One and Week Two plans by the number planned in Week One. Answers the question:

How well are we anticipating assignments one week ahead?

Example Lookahead Process Measurements

Completed	Week 1	Week 2
A	A	A
D	B	B
	D	C
	E	

$$PPC_1 = \frac{AD}{ABDE} = 50\%$$

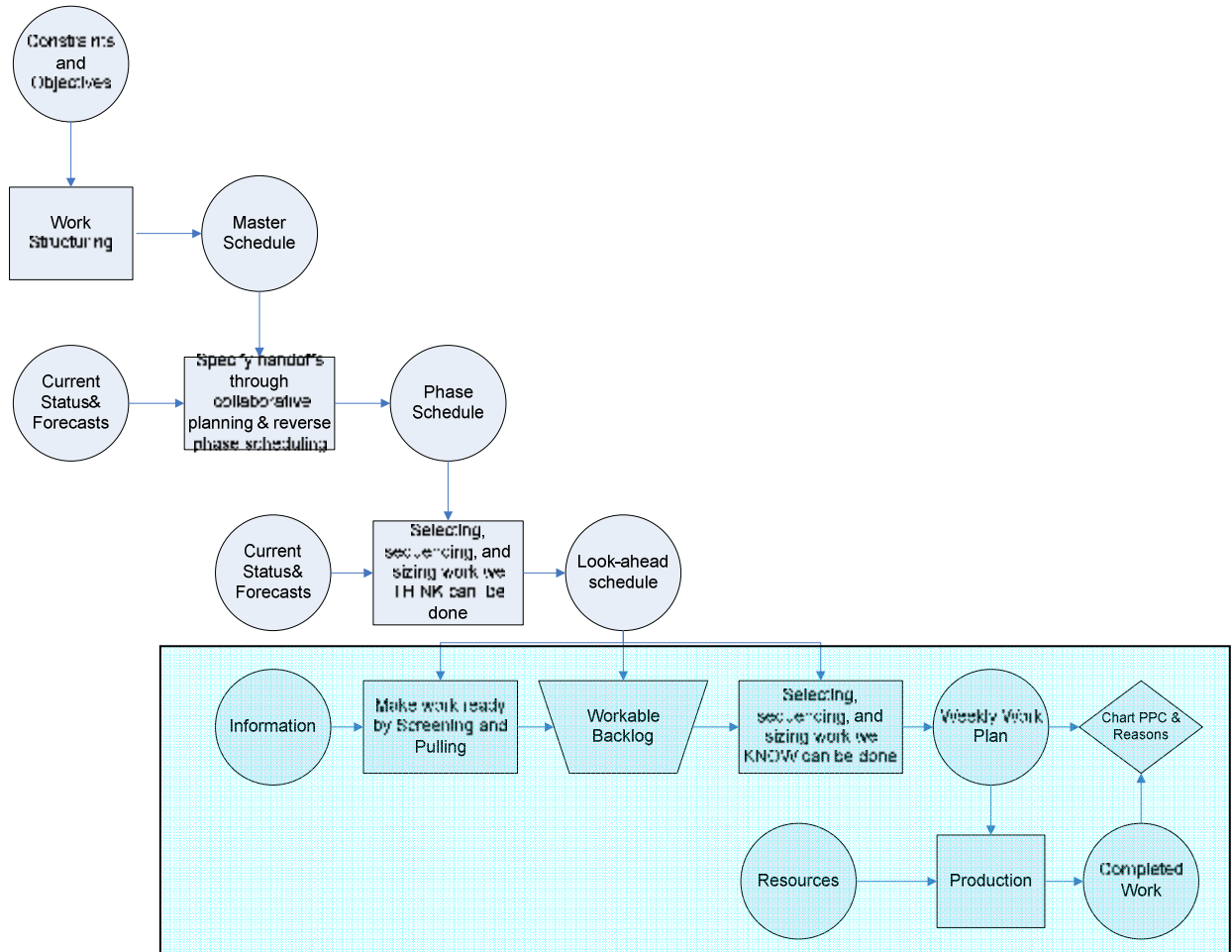
$$AMR_2 = \frac{AB}{ABC} = 67\%$$

$$PPC_2 = \frac{A}{ABC} = 33\%$$

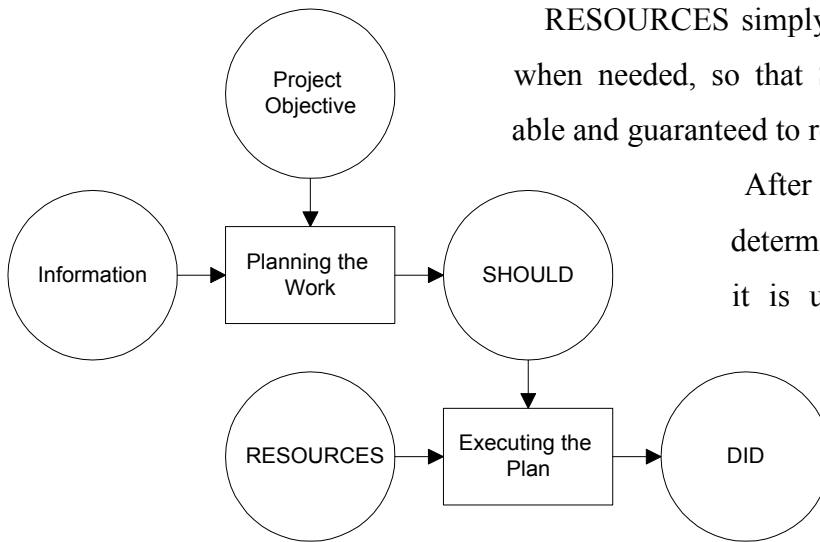
$$AA_2 = \frac{AB}{ABDE} = 50\%$$

WEEKLY WORK PLANNING

Weekly work planning is planning with the highest level of detail prior to carrying out the work. It is done by designers, shop floor supervisors, construction foremen, and numerous others who immediately supervise those doing the work.



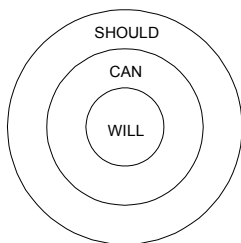
The traditional management approach for weekly work planning is to define activities and schedule work to be done, prior to the start of that work, in terms of what SHOULD be done. Activities are identified, timed, and sequenced so as to best serve the project objectives. Those doing the work, that is: design squads or production crews—throughout this workbook generically called the **production units**—are being committed by management to doing (WILL) whatever the schedule says SHOULD be done, with no real consideration for what they are actually able to do (CAN) at any specific point in time.



RESOURCES simply are assumed to be available when needed, so that SHOULD presumably is doable and guaranteed to result in DID.

After the schedule has been determined and as work progresses, it is up those doing the work to gather resources on hand and to adhere to the schedule as well as they can.

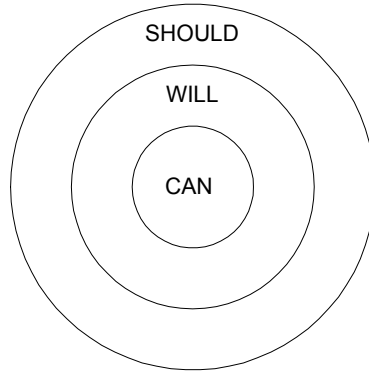
By contrast, **assume that planning means selecting from what SHOULD be done to complete a project and deciding for a given time frame what WILL be done. Recognize that because of resource constraints, not all CAN be done**, and accordingly:



If a subset of what SHOULD be done CAN be done, and a subset of what CAN be done WILL be done, then there is a high likelihood¹ for what has been planned (WILL) to be successfully completed (DID).

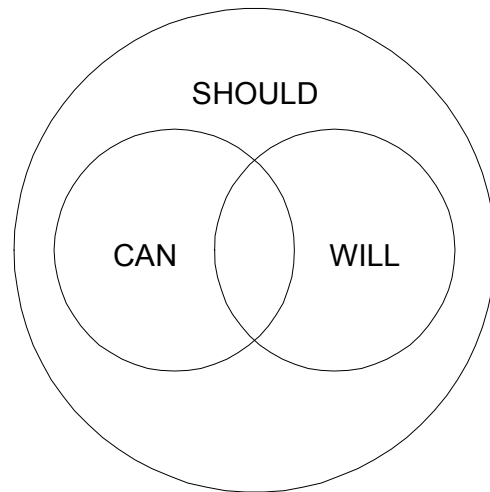
¹ Note that 100% success is never guaranteed as unforeseen plan execution failures may occur (e.g., due to machine breakdown or accidents).

If CAN is a subset
of WILL,



then *not* all commitments (WILL) that have been made during planning CAN be successfully pursued, so the plan is doomed to fail (DID differs from SHOULD).

Most construction projects are best characterized by CAN and WILL both being subsets of SHOULD. At best, CAN and WILL partially overlap with each other. If the plan is developed (WILL) without knowing what CAN be done, the production unit must find out what intersection exists between the two when they try to execute the plan.

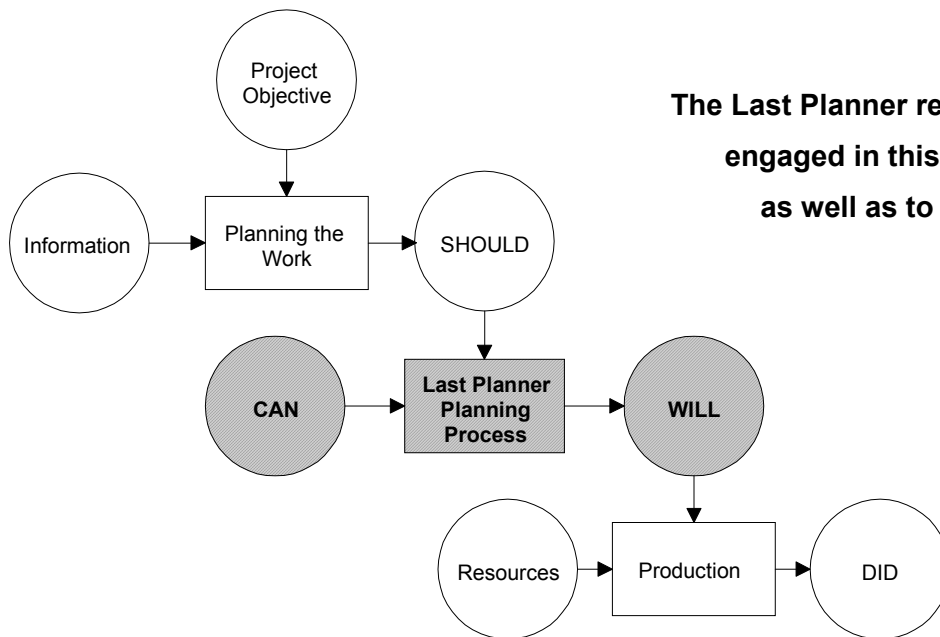


THE LAST PLANNER

Finding out what CAN be done *at the time the work is to be performed* not only is a time-consuming endeavor when pressure for output is high, it also defeats the very purpose of planning.

The production unit must plan its work in advance of executing its work. Advance planning allows for time to design the operations and study the work methods to be used. It also allows for time to address problems identified during planning that could be resolved prior to executing work.

The production unit must therefore perform this last step in planning—whence **The Last Planner**—a reasonable time prior to performing work. This step is to enable them to identify what part of the work that SHOULD be done CAN be done, and then commit (WILL) to doing only that kind of work.



The Last Planner refers to the person engaged in this planning process as well as to the process itself.

The resulting Last Planner's work plan thus reflects that what WILL be done, CAN be done, not merely what SHOULD be done.

The Last Planner's Weekly Work Plan is a **commitment plan**. By committing only to work that CAN be done, the Last Planner **shields** production units from upstream uncertainty and variability. The production unit will therefore be more likely to accomplish what they set out to do. This increased **reliability of the plan** increases performance, not only of the production unit that executes the Weekly Work Plan, but also of production units downstream as they can better plan when work is reliably released to them.

When it is impossible to determine what and how much work will be available at a future time, it is impossible for a production unit to arrange for the specific resources needed, and it is impractical to develop detailed methods or make specific preparations for doing what could be widely different types of work. **Thus the certainty of work flow from one production unit to the next is a key to productivity.**

The alternative strategy is one of flexibility. This means mobilizing resources sufficient to do whatever work happens to come through, allowing for multiple stops and starts of operations best performed as a whole, inefficient sequencing of tasks, and inability to do detailed advance planning.

When the flexibility strategy is adopted by a production unit, it also passes on the work flow uncertainty to its customer processes, thus multiplying the uncertainty and the expense. However, the flexibility strategy seems relatively easy to carry out! The increased costs can be at least partially offset by blaming others for failing to keep their commitments. It may appear to be the only alternative for participants interdependent with others in the production process, but organizationally independent and uncoordinated.

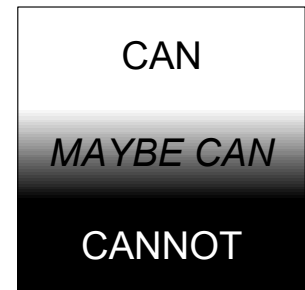
Shielding production is an alternative strategy in conditions of work flow uncertainty. Shielding is accomplished by making quality assignments, thereby increasing the reliability of commitment plans such as the Last Planner's Weekly Work Plans. Implementation of the Last Planner process therefore results in more reliable flow and higher throughput of the production system.

LEAN CONSTRUCTION PLANNING SYSTEM

Last Planner is a planning system that implements lean construction. The Weekly Work Plan is the most detailed plan in the system. It directly drives the production process.

The Weekly Work Plan is developed by selecting, sequencing, and sizing work we *KNOW CAN* be done. Work that the Last Planner *DOES NOT KNOW CAN* be done should not be assigned.

The Last Planner thus recognizes that there is a gray zone between knowing for certain something can be done versus knowing for certain something cannot be done. By recognizing a *MAYBE CAN* zone exists, the Last Planner acknowledges there is uncertainty regarding the executability of work. A work assignment may be constrained and constraints must get removed before the Last Planner will be certain that the work *CAN* be done.



If, as a result of assigning only work that *CAN* be done, the production crew is idle for a significant amount of time, supervisors will certainly notice²! It is then up to them to take action and remedy the problem by **making work ready** so production units will have sound or ready work to choose from. To make ready is to take actions needed to remove constraints from assignments to make them sound.

Making work ready is done in the lookahead process. Each week, the lookahead process will look one week further into the future and its first week will roll over to become the Weekly Work Plan. The lookahead process yields a **Lookahead Schedule** by selecting, sequencing, and sizing work we *THINK CAN* be done, using current status information and forecasts about anticipated availability of resources. Lookahead activities that do not meet the quality criteria of the Last Planner will have to be made ready.

² This is akin to stopping the assembly line in manufacturing.

The Lookahead is a breakout of the **Master Schedule** and **Phase Schedule** produced during front end planning. So, Master and Phase Schedule activities are exploded into more detail when creating the Lookahead Schedule. Activity explosion means expressing that task in greater detail, typically by producing a flow diagram of the process of which the output is the activity being exploded, then determining the sub-tasks needed to make the activity into a task ready for assignment and execution when scheduled.

Sub-tasks are categorized in terms of the **activity definition model**, resulting in actions to clarify or specify directives, requests for prerequisites from suppliers, and reservation of needed resources.

The Master Schedule covers an entire project. By contrast, the Lookahead Schedule typically spans only 5 to 6 weeks out into the future because uncertainty about what is to come later renders planning in greater detail meaningless. Both the Lookahead and the Weekly Work Plan increasingly explode tasks to be performed, taking into account actual circumstances. The Lookahead and in turn the Weekly Work Plan cover shorter time spans into the immediate future but reflect higher degrees of confidence that work will be executable.

Our focus here is on Weekly Work Planning.

An LCI companion workbook describes Lookahead Planning in more detail.

WHO IS THE LAST PLANNER?

The Last Planner is the person directly overseeing the work done by a production unit. The Last Planner typically is responsible and accountable for the unit's ability to produce and for the output they produce. The Last Planner may self-perform some of the work.

The Last Planner in design may be the design lead. The Last Planner for the general contractor may be a project engineer or an area superintendent. The Last Planner for the specialty contractor may be the crew foreman.

You can be a Last Planner!

QUALITY CRITERIA FOR ASSIGNMENTS

The Last Planner uses information about resource availability to move into the Weekly Work Plan selected activities that satisfy certain criteria and that are shown in the first week of the Lookahead Schedule. Activities that do not meet these criteria will have to be made ready first.

Choosing what work WILL be performed in the next week from what CAN be performed is termed **making quality assignments**. Weekly Work Plans are effective when assignments meet five specific quality criteria, namely:

- 1 **Definition:** Are assignments specific enough that the right type and amount of information or materials can be collected, work can be coordinated with other disciplines or trades, and it is possible to tell at the end of the week if the assignment has been completed?
- 2 **Soundness:** Are all assignments workable? Do you understand what is required? Do you have what you need from others, are all materials on hand; is design complete; is prerequisite work complete, etc.? Note that some make-ready work will remain for to be done during the week, e.g., meeting with other designers or fabricators, coordinating with trades working in the same area, moving materials to the point of installation, etc. Nonetheless, the intent is to do whatever can be done to get the work ready before the week in which it is to be done.
- 3 **Sequence:** Are assignments selected from those that are sound in priority order and in order of workability? Will doing these assignments release work needed by someone else? Are additional lower-priority assignments identified as workable backlog, that is, are additional quality tasks available in case assignments fail or productivity exceeds expectations?
- 4 **Size:** Are assignments sized to the productive capability of each individual or group while still being achievable within the plan period?
- 5 **Learning:** Are assignments that are not completed within the week tracked, reasons for deviation identified, and action taken?

Having a plan that meets these quality criteria does not guarantee success. A plan could always fail in execution. However, the purpose of the Last Planner is to help minimize plan quality failures so that unnecessary failures can be avoided.

Only assignments that meet these quality criteria may be put on a Weekly Work Plan.

The reason for making only quality assignments is to shield the production crew from uncertainties in workflow.

WORKABLE BACKLOG

Capacity limitations of the production unit may prevent the Last Planner from assigning all work shown in the first week of the Lookahead that satisfy the definition, soundness, and sequence criteria. That is, there may be more work made ready than a production unit can reasonably be expected to complete in any week. The sizing criterion dictates that the Last Planner assign only work that is likely to get completed in its entirety during the week it is assigned. Overloading a production unit is held against the performance of the Last Planner as assigned work that remains incomplete counts against the plan reliability measure.

Ready work that cannot be assigned is recorded as **Workable Backlog** on the Weekly Work Plan. Should the production unit for any reason not be able to complete an assignment on their Weekly Work Plan, or should they complete assignments sooner than expected, the Workable Backlog will provide them with other work so they need not be idle or wind up doing haphazardly-chosen or out-of-sequence work. Beware turning to tasks that cause later work to be more costly or difficult. Items in workable backlog must meet the same quality criteria as do priority assignments for the week.

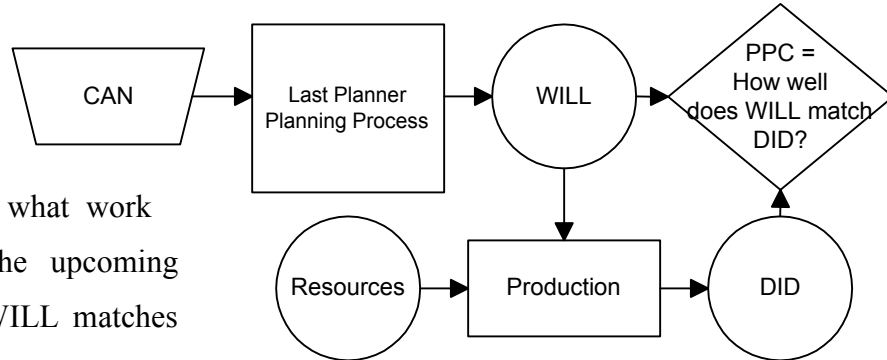
As mentioned previously, the Last Planner aims at creating a reliable work flow for the immediate production unit that will execute the Weekly Work Plan as well as production units downstream. This plan reliability is key to system performance. Accordingly, the Last Planner will **underload** the production unit, that is, make assignments to a production unit or resource within a production unit that absorb less than 100% of its capacity. An underloaded production unit will be able to accommodate variation in processing time or production rate for work flowing towards it. Underloading also creates release time for workers to take part in training or learning, conducting first-run studies, implementing process improvements, or for equipment to be maintained.

MEASURING PLANNING SYSTEM PERFORMANCE WITH PPC

The Last Planner needs a performance measure to gauge the quality of each Weekly Work Plan. Measuring quality is a first step towards learning about failure and then implementing improvement. The Last Planner's quality measure is **Percent Plan Complete** or **PPC**.

PPC is the number of actual completions divided by the number of assignments for a given week.

PPC assesses the extent to which the Last Planner was able to anticipate what work would get done in the upcoming week. It measures if WILL matches DID.



PPC thus reflects the reliability of planning system.

In the traditional, non-lean approach to planning, underloading resources would seem to cause the opposite; i.e., lower productivity. But the simple truth is that making assignments only loads a production unit if those assignments can actually be carried out. By making better assignments, including underloading, productivity improves along with the reliability of work flow from production unit to production unit.

The true balancing act is for the Last Planner to size assignments so that they underload production units just enough to allow for flow variability and for investment in developmental and improvement activities. There is much to be learned about these matters. Currently, LCI recommends loading at roughly 90% of capacity in order to absorb variability, unless you have measurement data to underload at a different level. This recommended percentage will be further validated as LCI research progresses.

**Complete or Not Complete?
That is the PPC Question.**

Whether or not an assignment has been completed requires a YES or NO answer. The Last Planner does not give credit to assignments on the Weekly Work Plan that remain incomplete at the end of the week, even though they may have been started. The rationale for this is that only completed work can be handed off to the next production unit, so if any part remains incomplete, no clean handoff can take place. In order to create reliable flow from one production unit to the next, end-of-week completion commitments must be met.

The Last Planner grants each production unit some leeway regarding schedule variation by assessing completion only once per week. Schedule variation may be caused by poor judgment regarding scope, resulting in poor estimates regarding the duration and timing for execution of assignments; unforeseen site conditions that cause work to be performed in an alternative sequence; unavailability of the specific worker to whom an assignment was made; or other reasons. As long as these variations do not prevent the assignment from being completed by the end of the week, the production unit will get full credit for it. Of course, the Last Planner will want to learn from any variation that occurred so similar variation may be prevented or at least accounted for in subsequently developed Weekly Work Plans.

The Last Planner can be implemented from the start of a project or it may be implemented on a project that already is underway. Dramatic performance improvements are likely to result! On this project, the Last Planner began screening assignments on 10/7/94. Within two weeks, weekly productivity—expressed as a performance factor in percent of budget, so a lower percentage is better—dropped dramatically and stayed significantly below the level it has been until project completion.

RELIABLE PROMISING

“Project coordination and control in the *Last Planner System* is principally the practice of eliciting reliable promises and declarations of completion of those activities that release work to others”. Since planning happens in conversation, reliable promising allows project work to stay in the desired sequence and advance as quickly as possible.

Reliable promising can be explained by the theory of language action shown in figure 10. Commitments start by request which analyzed. After some clarifications and cycles of negotiations, a commitment is made. Declaring completion signals an acceptable performance leading to satisfaction.

Reliable promising is the practice used to increase reliability of completion of project tasks thus creating reliable workflow. “Projects are promises to the client and their completion is realized by action coordinated through promising at every level”.

The Last Planner spawns many levels of conversation and coordination among project groups culminating into a commitment plan through articulating linguistic acts of declarations, requests, promises, assessments and assertions. These commitments are based on ongoing updates and evaluations of project status and connect already executed work to the intent to perform upcoming work and coordinate its completion.

In the context of completing promised activities and releasing work to others, reliable promising is accomplished when the following elements are satisfied:

- 1- The conditions of satisfaction are clear between the side making the promise and the customer (following activity).
- 2- The side making the promise is competent to perform or do I have access to competence (materials, tools, instructions, etc).
- 3- The side making the promise has estimated the amount of time to perform the activity fulfilling the promise and has reserved and allocated the capacity required.
- 4- The side making the promise is sincere and not having a private, unspoken conversation which contradicts fulfillment.
- 5- The side making the promise will exert every effort to perform take the responsibility for whatever consequences may ensue from not fulfilling the promise.

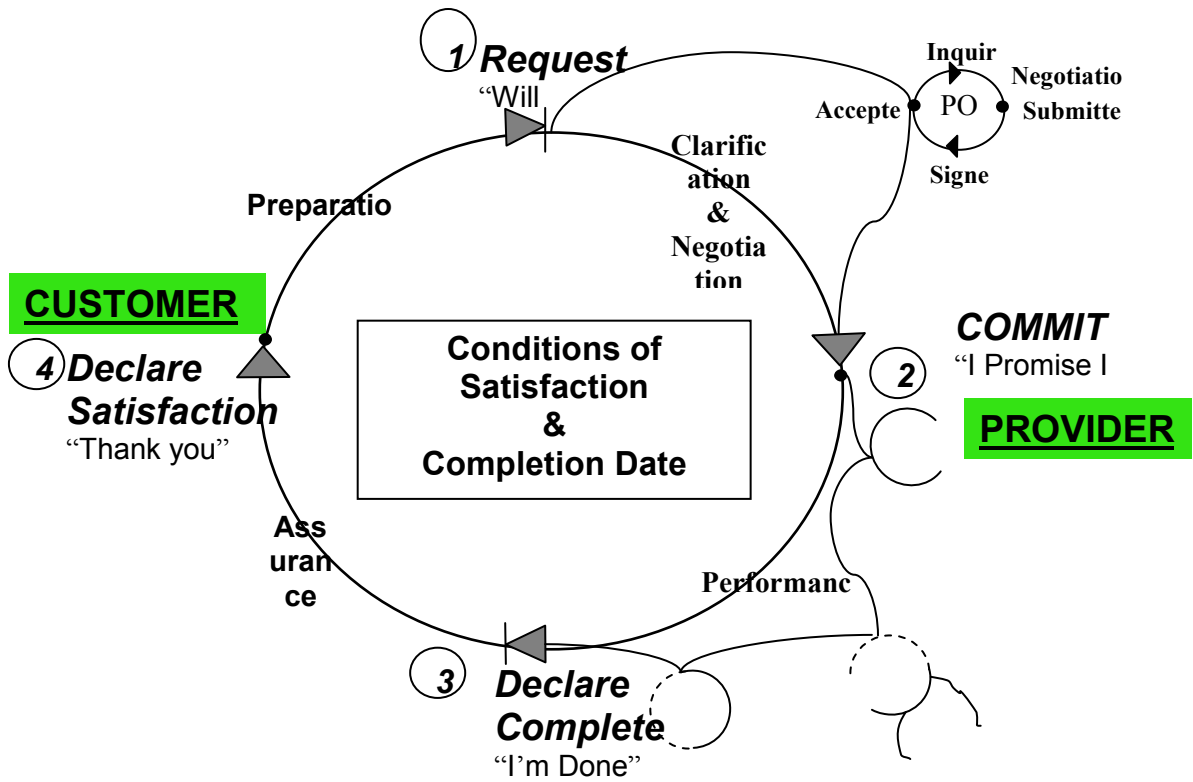
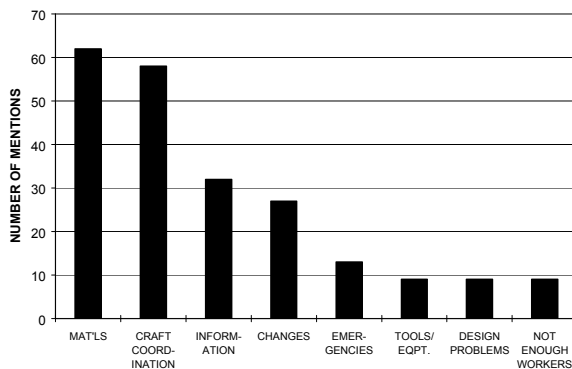


Figure 10: The Physics of coordination and reliable promising.

LEARNING FROM PLAN FAILURES

When an assignment is not completed by the end of the plan week, the Last Planner must record the **reasons** for non-completion. Reasons for plan failure fall into categories pertaining to directives, prerequisite work, resources, and process or output failures. Designers and contractors may recognize some of those commonly mentioned:

	DESIGN	CONSTRUCTION
Directives	changes in design criteria unaware of code requirements	changes in directives from superintendent not informed of performance standard
Prerequisite Work	information needed from owner waiting for vendor confirmation	need submittal approval materials did not arrive request for information unanswered other contractor still in area no access to work area
Resources	equipment failure unavailability of lead designer to grant approval	lack of tools and equipment labor shortage
Process or Output	insufficient time discovered calculation error	insufficient time no craft coordination weather emergency



Reasons for plan failure can be plotted based on their frequency of occurrence. This highlights which failures are predominant and where process improvement efforts may be most beneficial.

After noting reasons for non-completion, the Last Planner must perform a **root cause analysis**. The reason that is first apparent may in fact be a consequence of other actions and events that took place on the project. The Last Planner must get to the source of the action or event chain in order to learn how repeat failures can be prevented. The purpose is not to assign blame to any individual, but rather to help people understand how a change in their action might help prevent future plan failures.

The Five Whys

The five whys is a quality management technique of problem solving that tries to find the root cause of a problem. Once a problem occurs, workers should ask and answer why it occurred at least five times in succession until they identify an actionable root cause. The strategy for fixing the system is to eliminate the root cause to avoid repeat occurrence. The following demonstrates using the “Five Whys” technique to uncover the root cause of cutting into a dry wall to draw wiring.

1. Why was the dry wall cut?
 - The electrician had to pass inter-phone wiring
2. Why is the electrician passing wiring after dry wall closure?
 - The electrician is modifying the wiring as per the newly modified drawings.
3. Why didn't the electrician follow the modified drawings in the first place?
 - The foreman did not that this area should not start before the modified drawing is received.
4. Why didn't the foreman know about new change?
 - The area was scheduled on the weekly work plan
5. Why was the area scheduled on the weekly work plan?
 - Constraints analysis was not done during weekly work planning.

Asking why for five times uncovered the source of the problem where the last planner who is the foreman in charge did not perform constraints analysis to know that the area is subject to an owner change and work should not proceed until the change is issued. The solution would be weekly work planning sessions for removing constraints and making activities ready.

Reasons Analysis

The Reasons Analysis Hierarchy may help you determine root causes. For instance:

- B. If you did not have something you needed as a prerequisite to your process,
 - B.1 Did you request those needed prerequisites?
 - B.2 Was your request specific and complete?
 - B.3 Were you promised the prerequisite but did the provider not deliver? or
 - B.4 Were you not able to reach agreement with the supplier of the prerequisite?

Each of these in turn leads to further questions that will let you pin down the cause of failure, so you may be able to prevent it from reoccurring.

Examples of Reasons Analysis

Here are some of the common reasons for plan failure. Figure 11 is an important tool for tracking plan failures to learn from past failures and avoid them on future tasks.

A. I did not try to make a reliable promise because...

- I felt I had no choice but to say “yes”
- No request was made of me

B. Someone broke a promise to me....

- My priorities were changed
- Piping materials were not delivered by Pipes-R-Us
- The crane broke down

C. I tried to make a reliable promise, but.....

- did not remember to order the material
- overestimated the amount of work that could be completed
- did not make my promise contingent upon receiving an answer to RFI #71

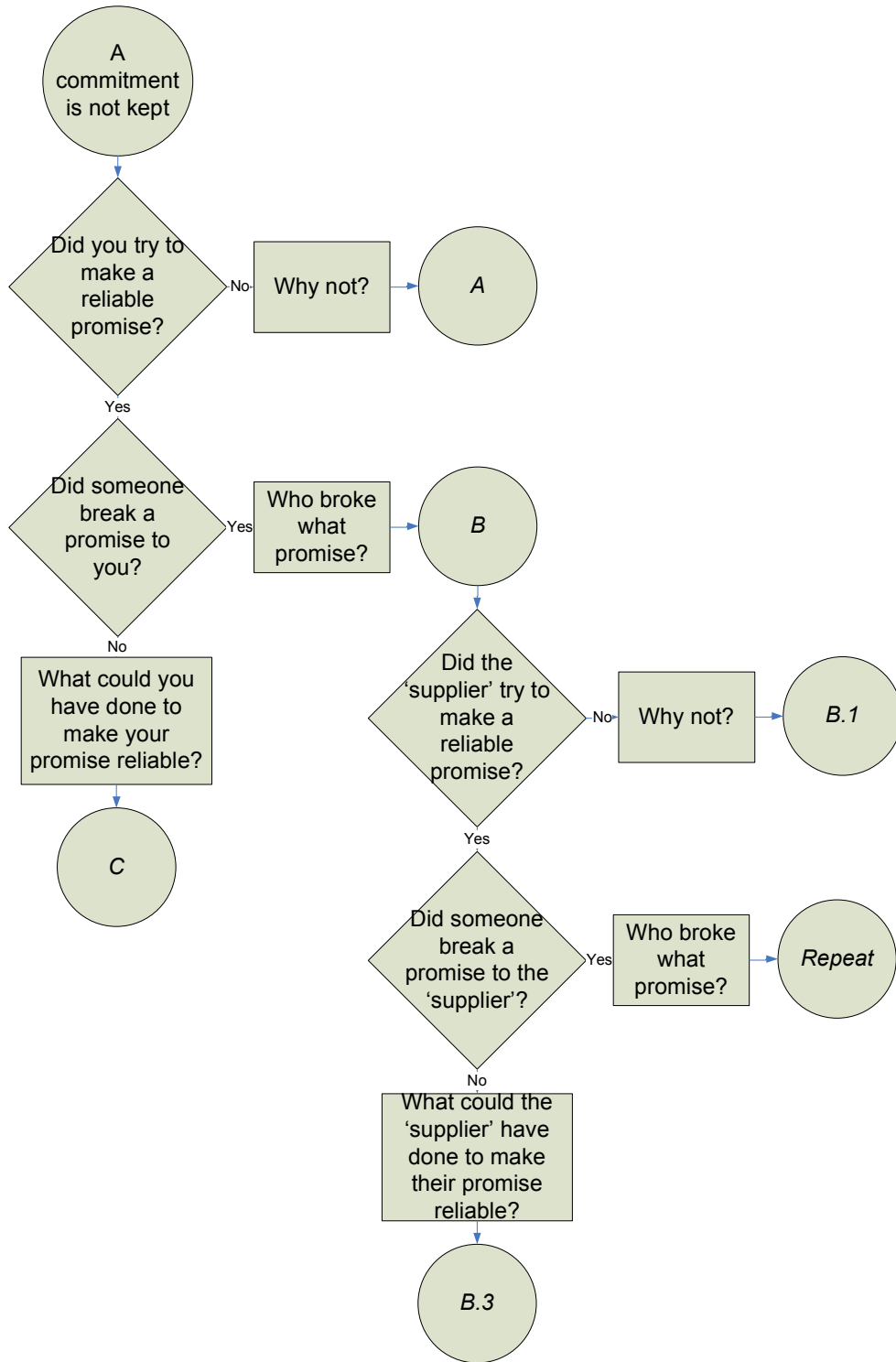
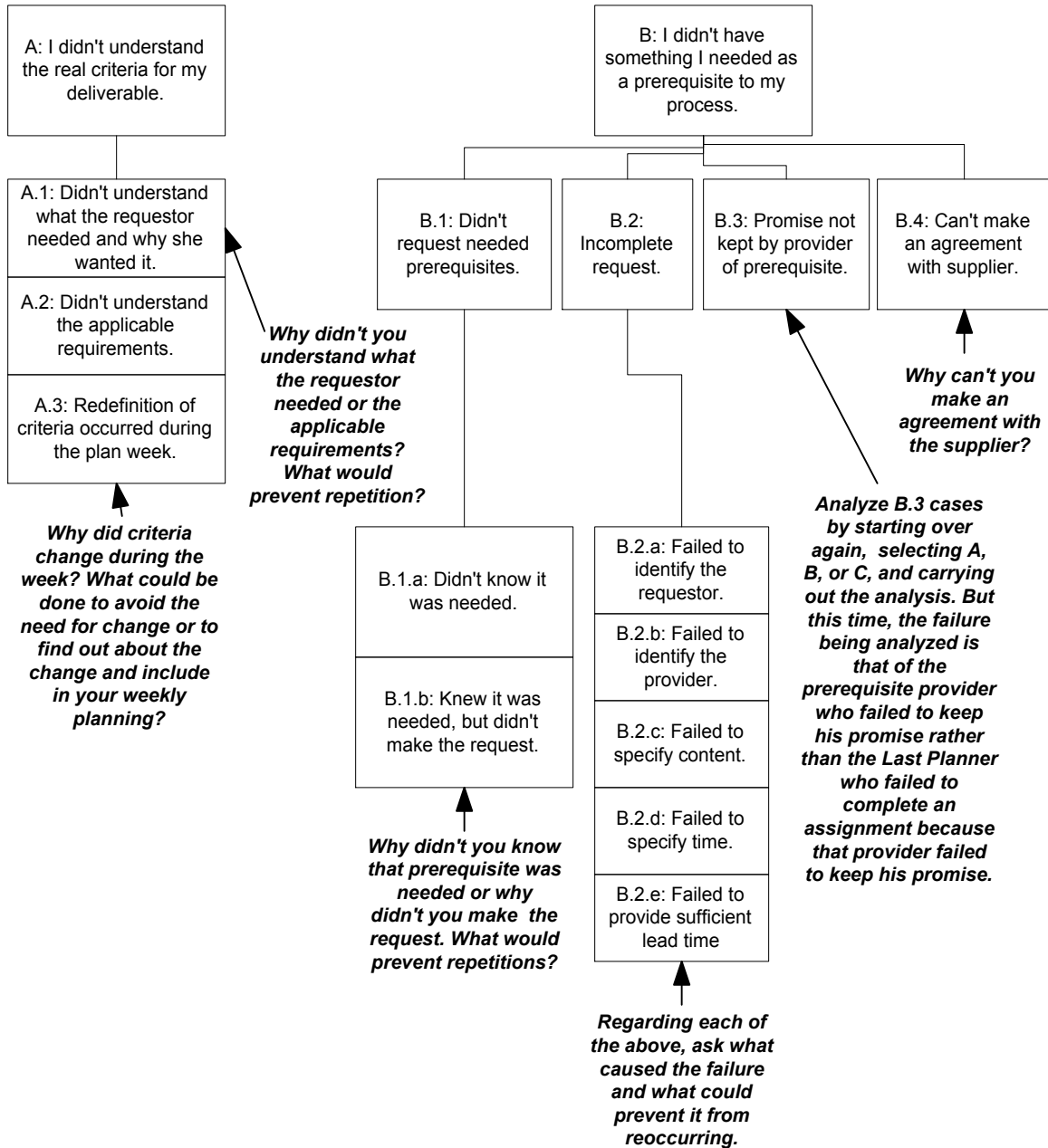
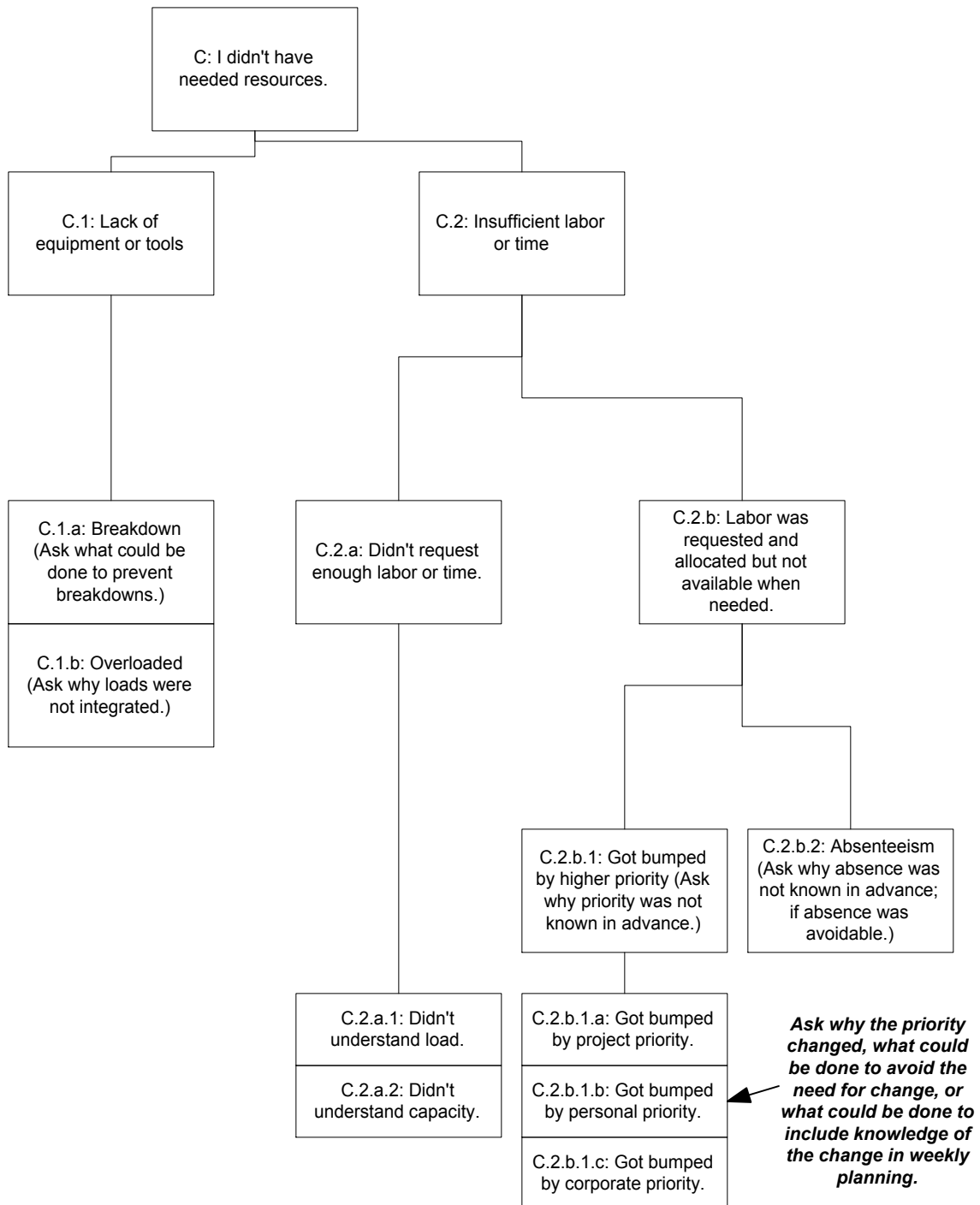


Figure 11: Analysis for reasons of plan failure.

Reasons Analysis Hierarchy - Criteria and Prerequisites



Reasons Analysis Hierarchy - Resources



SAMPLE WEEKLY WORK PLANS

So what does a Weekly Work Plan really look like? A Weekly Work Plan is a table with the following column headings:

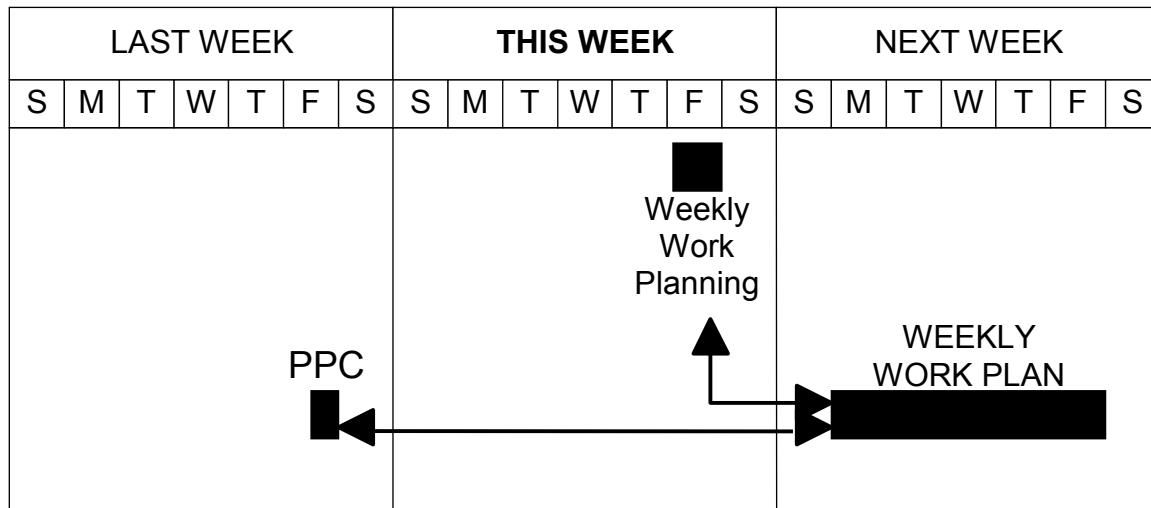
- Identification of the project
- Name of the Last Planner
- Date the plan is developed
- Days and dates covered by the plan
- Description of each assignment and the party responsible for executing it
- Make ready needs
- Check (yes/no) for completion of the assignment at the end of the week
- Reasons for variance if assignment was not completed

Weekly Work Plans may take on a different appearance depending on who the Last Planner is. Designers, contractors, and specialty contractors will want to reflect their plans with varying degrees of detail, depending on the circumstances. Their plans will also reflect how they have set up their planning cycle. Sample plans are shown in appendix 3 and 4..

WEEKLY WORK PLANNING CYCLE

Weekly Work Planning is done shortly before performing work. Assuming that the plan week begins on Mondays—though other plan weeks are possible—planning may be done during on Friday on the last working day of the week. Illustrated is a 5-day work week This meeting involves a meeting coordinator and all Last Planners on a project whose work is related by prerequisites, shared resources, directives, or other potential constraints. The purpose of the meeting is threefold:

- Assess and learn from last week's PPC,
- Create the work plan for the following week, and
- Determine make ready needs for the upcoming week.



Last Planners must bring to meeting their actual PPC data for last week's Weekly Work Plan with reasons identified for assignments that were not completed. This week's meeting is for all Last Planners to learn what the root causes were for their plan failures and identify how these can be prevented in the future. Prevention often requires consideration and action by other production units, so the meeting is to clarify who pays and who gains in order to balance fairness while all aim for improved system performance.

The current week's Weekly Work Plan and information on the status of work is to communicate how things are going and allow other production units to gain insight into plan changes or request adjustments from others.

Each Last Planner then puts forward their Weekly Work Plan for the next week. This information exchange combined with negotiation among Last Planners will help resolve sequencing alternatives where shared resources are involved.

Last Planners bring to the Weekly Work Planning meeting:	The coordinator brings:
<ul style="list-style-type: none"><input type="checkbox"/> Last week's Weekly Work Plan with PPC and reasons for plan failure identified;<input type="checkbox"/> This week's Weekly Work Plan and information on the status of work;<input type="checkbox"/> A first cut at next week's Weekly Work Plan and a list of make ready work; and<input type="checkbox"/> Their production unit's Lookahead Schedule.	<ul style="list-style-type: none"><input type="checkbox"/> The project's Master and Lookahead Schedules<input type="checkbox"/> Composite Weekly Work Plans for last week and this week that summarize commitments regarding work assignments made by Last Planners;<input type="checkbox"/> Status information from the client, regulators, designers, suppliers, project managers, production units, or others with a stake in the project.

In addition, all Last Planners must check on the completion of make ready work for next weeks' assignments. Some may yet have to be completed in the upcoming week and will thus require timely tracking. If this work is not ready in time, the corresponding assignment is doomed to fail. The production unit should therefore not even start this work, but rather, select an alternative assignment on their workable backlog.

Before the end of work Friday, all Last Planners finalize their Weekly Work Plans and distribute them to their production units as well as supervisors.

Daily Work Plans/meetings

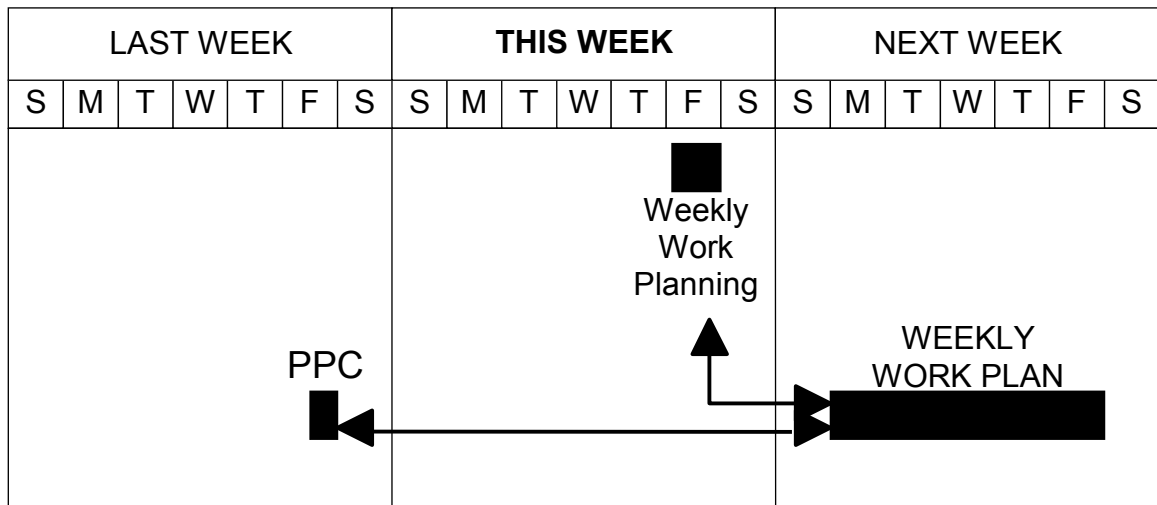
First line supervisors should meet early morning on a daily basis with their work teams to assess the situation and set targets for the day. Factors affecting resources are evaluated (machine breakdowns, absenteeism, weather...etc) and adjustments are taken. This is used as a fine tuning tool to steer the weekly work plan toward successful execution.

Now it's your turn to get some hands-on experience with Weekly Work Planning.

EXERCISE I: EVALUATE LAST WEEK'S PERFORMANCE

You are the coordinator for work on a building construction project and have just checked off the completion of assignments on last week's Weekly Work Plan, shown on the following page. Evaluate the performance of your team by performing the following task and answering the questions:

1. Calculate the PPC.
2. Review the reasons for non-completion of assignments. Do they sound familiar? What other reasons have you heard in your practice?
3. From your experience, what might be root causes for these plan failures? Give examples.
4. Does completing work on the Workable Backlog count towards PPC?
5. What could the Last Planner have done to increase the likelihood of achieving a higher PPC?
6. What could others have done to increase the likelihood of achieving a higher PPC?



Last Planner Workbook: Performance Evaluation
www.leanconstruction.org

Project:

Prepared by:

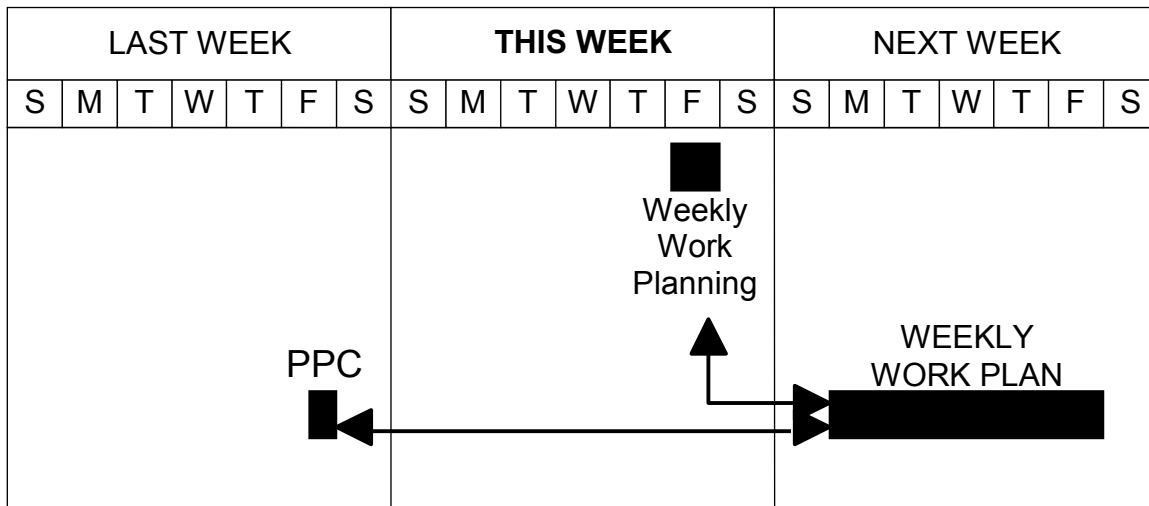
Date Prepared:

1	Responsible Party	Activity Description Remember the Five Criteria for Release of Assignments Defined - Sound - Proper Sequence - Right Size - Able to Learn	Make Ready Needs Work That Must and Can Be Performed Prior To Release of This Assignment	Period to Perform the Work							PPC Analysis	
				M	T	W	TH	F	S	Y	N	Reasons For Variance
				21	22	23	24	25	26			
1	Rebar-sub	Rebar erection for 1st floor columns 5,6,7,8	Rebar trailer on site Mon morning	X						X		
2	Electrical Sub	Electrical inserts/rough-in for 1sr floor wall w1		X						X		
3	GC	Formwork for 1st floor wall w1	Sign-off of rebar inspection on Mon		X	X				X		arrived late, did not complete inspection
4	Mechanical	Builder's work or mechanical crossings in 1st floor wall w1	Coordination shop drawings		X					X		Delay in approval of coordinated dwgs
5	Electrical Sub	Electrical inserts/rough-in for columns 5,6,7,8	GI connectors		X					X		missing materials
7	GC	Formwork for 1st floor columns 5,6,7,8	Sign-off of rebar inspection			X				X		
8	GC	Pour concrete for 1st floor wall w1	Sign-off of services inspection				X			X		
9	GC	Pour concrete for 1st floor columns 5,6,7,8					X			X		Formwork not ready
10	GC	Strip formwork for columns 1,2,3,4		X								
11	GC	2nd floor Slab falsework for area 1			X	X				X		
12	GC	2nd floor Slab deck formwork for area 1				X	X	X		X		
13	Rebar-sub	2nd floor rebar installation for area 1	Deck is ready						X	X		60% done, delayed by deck formwork
14												
	Workable Backlog											
1	Rebar-sub	Rebar erection for 1st floor columns 9,10,11,12								X		
2	Electrical Sub	Electrical inserts/rough-in for columns 9,10,11,12										
3	GC	Formwork for 1st floor columns 9,10,11,12'										
4												
5												

EXERCISE II: CONSTRAINTS ANALYSIS

The first week on your Look-ahead Schedule includes the tasks shown in the table on the next page. You have already identified the constraints and filled out an 'X' to indicate if there is no constraint of a certain category.

1. Are these tasks well defined? What exactly do they entail?
2. Check which of these tasks are sound so they can be considered for assignment by the Last Planner, and place a check mark in the 'Sound?' column.
3. What may be some of the make ready needs for the tasks listed?
4. When do you expect make ready work to get done? Who will do it?
5. How likely do you think is it, that make ready work will get done when expected?
6. What would you do if make ready work did not get done when expected?



Last Planner-Lookahead Constraints Analysis

Project name: _____

Prepared by: _____

Run Date: _____

Activity ID	Activity Description	Planned Start Date	Responsible Party	Contract / Change Orders	Design			Materials	Labor	Equipment	Prereq Work	Space	Sound?	Comments
					AE Complete	Submittals	RFI's							
11	Rebar erection for 1st floor columns 5,6,7,8	1/15/2007	Rebar-sub	X	X	X	X	Delivery Mon AM	X	X	X	X		
12	Electrical inserts/rough-in for 1st floor wall w1	1/15/2007	Electrical Sub	X	X	X	X	X	X	X	X	X		
13	Formwork for 1st side for 1st floor wall w1	1/15/2007	GC	X	X	X	X	X	X	X	X	X		
14	Mechanical penetrations in 1st floor wall w1	1/15/2007	Mechanical	X	Shop Dwg approval	Puddle flange (Seal)	X	X	X	X	X	X		
15	Strip formwork for columns 1,2,3,4	1/15/2007	GC	X	X	X	X	X	X	X	X	X		
16	Electrical inserts/rough-in for columns 5,6,7,8	1/16/2007	Electrical Sub	X	X	X	X	GI couplers	X	X	X	X		
17	Formwork for 1st floor columns 5,6,7,8	1/17/2007	GC	X	X	X	X	X	X	X	Inspection	X		
18	Formwork for 2nd side for 1st floor wall w1	1/16/2007	GC	X	X	X	X	X	X	X	Inspection	X		
19	Pour concrete for 1st floor wall w1	1/17/2007	GC	X	X	X	X	X	X	X	Inspection	X		
20	Pour concrete for 1st floor columns 5,6,7,8	1/18/2007	GC	X	X	X	X	X	X	X	Inspection	X		
21	2nd floor Slab falsework for area 1	1/16/2007	GC	X	X	X	X	X	Carpenters	X	X	X		
22	2nd floor Slab deck formwork for area 1	1/17/2007	GC	X	X	X	X	Plywood delivery Tu. p.m.	X	X	X	X		
23	2nd floor rebar installation for area 1	1/18/2007	GC	X	X	X	X	X	X	X	Deck	X		
24	2nd floor slab electrical rough-in works	1/19/2007	Electrical Sub	X	X	X	RFI # 33	X	X	X	X	X		
25	2nd floor slab mechanical penetrations (service crossings and box outs)	1/19/2007	Mechanical	Yes	Revision awaited	X	X	X	X	X	X	X		
26	Falsework for 1st floor staircase 1	1/19/2007	GC	X	X	X	X	Scaffold delivery Wed Am	X	X	X	X		
27	Preassemble forms for lift wall	1/19/2007	GC	X	X	X	X	X	X	X	X	X		

If an activity is constrained place a note in the cell, if an activity is not constrained place an X in the cell

EXERCISE III: WEEKLY WORK PLAN ADJUSTMENT

Just prior to Friday's Weekly Work Plan Meeting, you get the following information.

(1) The lumber supplier returns the call you made to confirm your shipment. He tells you that the plywood panels promised for delivery on Tuesday afternoon will be delivered two days later.

(2) A change in electrical sockets for columns 5,6,7,8 is issued on Monday. New sockets are not available on site with the electrical subcontractor. They will be received on site after one day and installed by the end of the same day.

Update your Weekly Work Plan.

Your Weekly Work Plan is now ready for release. Who all will you give a copy to?

EXERCISE IV: WEEKLY WORK PLAN WITH ACTION ITEMS

The constraints analysis reveals which tasks on the Look-ahead are sound and which ones remain to be made ready.

1. What are the remaining quality criteria the Last Planner must consider prior to assigning work?

The Last Planner is working with two crews. One crew includes 4 Carpenters, 2 apprentices, and 2 helpers. The other crew includes the Last Planner and 2 carpenters plus 2 apprentices and 1 helper. Since activity 15 is a predecessor for activity 21 and activity 21 is a predecessor for 22, only one crew at a time will be able to work on tasks 18 and 19. Because of their different skill sets and crew size, the crews will work at a different pace depending on the nature of their assignment. This is reflected in the number of days of work contents per crew for each assignment.

Activity ID	Activity Description	Work Contents	
		Crew 1	Crew 2
13	Formwork for 1 st side of wall w1 on 1 st floor	1	1.25
15	Strip formwork for columns 1,2,3,4	0.5	0.5
17	Formwork for 1 st floor columns 5,6,7,8	0.75	1
18	Formwork for 2 nd side of wall w1 on 1 st floor	1	1.25
21	2 nd floor falsework for area 1	1	1.25
22	2 nd floor deck for area 1	1.5	2
26	False work for 1 st floor stair case 1	2	2.75
27	Preassemble forms for lift wall	1	1.5

Use this information regarding the capacity of the production units to create a Weekly Work Plan. Use the form on the following page.

Identify any make ready work that remains to be done during the plan week.

How did you decide what work to make into priority assignments and what work to treat as Workable Backlog?

EXERCISE V: EXECUTING A WEEKLY WORK PLAN

Despite the best planning efforts, unlikely events and unforeseen conditions may always crop up. Assume that you find out about the following events at the beginning of the week:

1. (1) Two members of crew 1 do not show up to work on Monday.
(2) Crane break down for one day delayed falsework/scaffold shifting to 1st floor.
(3) You learn about a pending design change for stair case 1.
(4) The lift wall rebars are in place.
Show how these affect your Weekly Work Plan.
2. *At the end of the week, assess your PPC. Write down reasons for non-completion of activities and determine root causes.*
3. *What do you learn from the occurrence of these plan changes?*
4. *How will they affect your future planning efforts?*

FOOD FOR THOUGHT

- 1. Using data from the exercises you have just completed, what are the advantages and disadvantages of using the Last Planner?*
- 2. How do these compare to advantages and disadvantages of the planning system you currently are using in your organization?*

The Last Planner shields production units from variability. Some of the benefits of shielding are:

1. It provides the production unit with the ability to plan and prepare for specific tasks they will perform in the following week. The production unit does not invest time in any excess preparation in order to maintain flexibility.
2. Shielding injects reliability, certainty, and honesty into the work environment because the planning system relies on commitments and measures to what extent commitments are adhered to.
3. Shielding promotes accountability.
4. Shielding improves control.
5. Shielding facilitates improvement by reducing system noise; the planning system becomes more transparent and production units can be explicit about their requirements and root causes for failure.
6. Shielding increases productivity by reducing non-productive time. It also releases time and energy for improving work methods.

A word of caution is in order regarding the relationship between PPC and productivity. Do not mistake one for the other! PPC measures reliability of the planning system. Productivity gauges how much work gets done. These are different things. PPC is only a relative measure that cannot exceed 100%. Productivity as commonly measured may be larger or smaller than 100%. Nevertheless, implementation of the Last Planner in practice has demonstrated that there is a strong correlation between increasing PPC and increasing productivity.

SUMMARY OF LESSONS LEARNED

Using this workbook you have learned about the Last Planner whose aim is to increase the reliability of a planning system and thereby improve performance. The Last Planner starts with weekly work planning, that is, the process of making assignments to production units, which must get done just prior to executing work. To achieve effective production control, the Last Planner's planning system is structured around the assignment as the unit of analysis. Quality assignments meet definition, soundness, sizing, sequence, and learning criteria.

The Last Planner considers quality criteria for assignments in advance of committing production units to doing work in order to shield these units from uncertainty and variability. The plan's success at reliably forecasting what work will get accomplished by the end of the week is measured in terms of Percent Plan Complete or PPC. Root causes for plan failure are then investigated at the end of each week so they may be avoided in the future.

No planner is perfect, but we must always be learning how to be better planners.

Increasing PPC leads to increased performance, not only of the production unit that executes the Weekly Work Plan, but also of production units downstream as they can better plan when work is reliably released to them. Implementation of the Last Planner therefore results in more reliable flow and higher throughput of the production system.

Commitment-level planning resulting in Weekly Work Plans as presented in this workbook is only a part of the Last Planner system. An LCI companion workshop and associated workbook describes the process of Lookahead planning that is necessary to effectively implement Weekly Work Planning. Lookahead planning is complemented by initial planning, which yields a Master Schedule with overall project budget and timing information.

The Master Schedule provides a coordinating map that pushes completions and deliveries onto a project. Lookahead planning details and adjusts budgets and schedules, pulling resources into play and screening out activities for which resources are not likely to be available. Commitment planning involves committing to what will be done, after evaluating 'should' against 'can', based on actual receipt of resources and completion of prerequisites.

WEEKLY WORK PLANNING IN YOUR COMPANY

Have you decided to start implementing the Last Planner in your company? Recommended steps are:

1. Identify a pilot project.
2. Obtain management support to implement the Last Planner process.
3. Identify the Last Planner(s) on this project.

Learn as much as you can about the Last Planner and lean construction in general. To read up on lean construction, visit our LCI web site at:

www.leanconstruction.org/papers.htm. Implementation of this new production system will require major organizational change and you will have to answer numerous practical questions such as:

4. Have all Last Planners been instructed in the Weekly Work Planning process and techniques?
5. What weekly planning cycle will you adopt?
6. Who should be involved in Weekly Work Planning meetings?
7. What forms will you use?

Weekly work plans in Excel spreadsheet format can be downloaded from our website at www.leanconstruction.org. You will need to get a password from your workshop instructor. Samples of the forms used in this workbook are included in Appendix 2, 3, and 4 for you to photocopy and use. You will find it more convenient, though, to follow the practice of logging Constraints Analyses or Weekly Work Plans as separate sheets of an Excel workbook so the electronic copies are more practical to use.

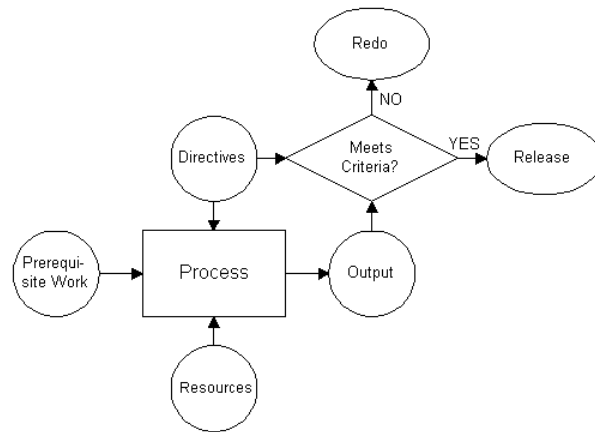
Good luck with the Last Planner! Please keep us posted on your PPC measurements and what you learn from them.

APPENDIX 1: LEAN CONSTRUCTION GLOSSARY

This lean construction glossary is available on the web at:

www.leanconstruction.org/glossary.htm

activity definition model (ADM): An input-process-output representation of design tasks or construction processes. The model depicts the specification of directives (entering the process rectangle from above), prerequisites (including materials and information to be transformed into the desired output, entering the process rectangle from the left), and resources (entering the process rectangle from below). It also shows an inspection process resulting either in redo or release to the customer process. The model is used as a guide to exploding scheduled tasks into a level of detail at which their readiness for execution can be assessed and advanced.



ADM: see activity definition model.

assignment: a directive or order given to a worker or workers directly producing or contributing to the production of design or construction.

Example: Scott, you and Julie are to make the changes in wall locations detailed in memo #123 by the end of the week. Anne, you find out what the building authorities will require for a structural permit.

backlog: see workable backlog.

buffer: a mechanism for deadening the force of a concussion; e.g., a capacity buffer is created by scheduling less than all the time available. If production falls behind schedule, there is capacity available for catching up. (Lean production/construction generally prefers capacity buffers to inventory buffers.)

capacity: the amount of work a production unit, whether individual or group, can accomplish in a given amount of time.

Example: Jim the engineer can perform 10 piping stress analyses per day on average, but the analyses to be done this week are particularly difficult. He will only be able to do 7. Jim's average capacity is 10, but his capacity for the specific work to be done this week is 7.

commitment planning: the bottom level in the planning system hierarchy, below lookahead planning, that results in commitments to deliver on which others in the production system can rely because they follow the rule that only sound assignments are to be accepted or made.

Example: On my work plan for next week, I have included providing Cheryl the soils data she needs to evaluate alternative substructure systems for the building. All known constraints have been removed from my task, I understand what's required and how the information will be used, and I have reserved needed labor and equipment.

conditions of satisfaction (COS): directives, often criteria, imposed by the entity initiating a process (usually the owner) that specify how success of the outcome will be gauged.

constraint: Something that stands in the way of a task being executable or sound. Typical constraints on design tasks are inputs from others, clarity of criteria for what is to be produced or provided, approvals or releases, and labor or equipment resources. Typical constraints on construction tasks are the completion of design or prerequisite work; availability of materials, information, and directives. Screening tasks for readiness is assessing the status of their constraints. Removing constraints is making a task ready to be assigned.

control: To cause events to conform to plan, or to initiate replanning and learning.

Example: Exploding master schedule activities into greater detail, screening the resultant tasks against constraints, and acting to remove those constraints are all control actions intended to cause events to conform to plan, or to identify as early as practical the need for replanning. Learning is initiated through analysis of reasons for failing to cause events to conform to plan.

COS: see conditions of satisfaction.

criteria (plural of criterion): Criteria are a subset of directives, specifically those used to evaluate process outputs.

customer: The user of one's output.

Example: John needs the results of our acoustical tests in order to select the best location for his mechanical equipment. John is our customer because he will use what we produce.

cycle time: The time it takes a product to go from beginning to end of a production process; i.e., the time it is work-in-process.

definition: Quality criterion for assignments that questions whether or not assignments are specific enough so that the right type and amount of information and materials can be collected, work can be coordinated with other disciplines or trades, and it is possible to tell at the end of the week if the assignment has been completed.

design: a type of goal-directed, reductive (not deductive) reasoning. There are always many possible designs, especially if one is willing to relax constraints.

Product design reasons from function to form. Process design reasons from ends to means.

design criteria: the characteristics required for acceptance of product or process design.

Example 1: The structural engineer needs both geometric and load inputs from the architect, mechanical engineer, and electrical engineer. Loads need only be accurate within 20%.

Example 2: The cladding design must be consistent with the architectural standards of the local historical society. In addition, it must be within the 2 million dollar budget and installable within a 6 week window concluding no later than April 6, 2000.

directive: instruction or order issued by a last planner to direct workers on what to do and possibly when or how to do it. Directives may apply to selection of prerequisites, resources, process execution, or criteria for output evaluation. See ADM.

exploding: Expressing a task in greater detail, typically by producing a flow diagram of the process of which the output is the task being exploded, then determining the sub-tasks needed to make the task ready for assignment and execution when scheduled. Sub-tasks are categorized in terms of the activity definition model, resulting in actions to clarify or specify directives, requests for prerequisites from suppliers, and reservation of needed resources.

first-run study: Trial execution of a process in order to determine the best means, methods, sequencing, etc. to perform it. First-run studies are done a few weeks ahead of the scheduled execution of the process, while there is time to acquire different or additional prerequisites and resources.

flow: see work flow.

front end planning: The top level in the planning system hierarchy, above lookahead planning, dedicated to articulating high-level activities and their duration and sequencing for an entire project and resulting in a master schedule. Also see lookahead planning and commitment planning.

input: The combination of directives, prerequisites, and resources needed to execute a process. See ADM.

inventory: Stock on hand; often divided between raw materials inventory, work-in-process, and finished goods inventory.

last planner: The person or group that makes assignments to direct workers. 'Squad boss' and 'discipline lead' are common names for last planners in design processes. 'Superintendent' (if a job is small) or 'foreman' are common names for last planners in construction processes.

learning: The process of gaining new knowledge or insights whose implementation may improve product and process development.

load: The amount of output expected from a production unit or individual worker within a given time. Within a weekly work plan, what is to be accomplished by a design squad or individual designer, engineer, draftsman, construction craftworker, crew, etc. A quality assignment 'loads' a resource within its capacity.

lookahead planning: The middle level in the planning system hierarchy, below front end planning and above commitment planning, dedicated to controlling the flow of work through the production system.

lookahead schedule: The output of lookahead planning, resulting from exploding master schedule activities by means of the activity definition model, screening the resultant tasks before allowing entry into the lookahead window or advancement within the window, and execution of actions needed to make tasks ready for assignment when scheduled. Lookahead schedules may be presented in list form or bar charts.

lookahead window: How far ahead of scheduled start activities in the master schedule are subjected to explosion, screening, or make ready. Typically lookahead windows extend from 3 to 12 weeks into the future.

make ready: 'To make ready' is to take actions needed to remove constraints from assignments to make them sound.

master schedule: Schedule produced during front end planning and covering an entire project, with activities to be exploded when creating the lookahead schedule.

output: The product or service resulting from execution of an activity or process.

percent plan complete: see PPC.

plan reliability: The extent to which a plan is an accurate forecast of future events, measured by PPC.

Example, if your weekly work plans have a 60% PPC, they accurately predict completion/release of 60% of the weekly assignments.

planning: Defining criteria for success and producing strategies and directives for achieving success.

PPC: percent plan complete; i.e., the number of planned completions divided into the number of actual completions, usually referring to activities on a weekly work plan.

prerequisite work: Work done by others on materials or information that serves as an input or substrate for your work.

Example: You need to know the surface area of glass, provided by the architect, in order to size cooling equipment.

production unit: a group of direct production workers that do or share responsibility for similar work, drawing on the same skills and techniques.

Example: a team of electrical designers and engineers responsible for a specific area or functions of a building.

productivity: the ratio of the output produced to the resources used in its production.

Example: x drawings per labor hour.

pulling: initiating the delivery of input based on the readiness of the process into which they will enter for transformation into outputs.

Example: Request delivery of prerequisite information at or before the time you will be ready to process that information. Note: what's different here is that the readiness of the process is known rather than wished. Either the process is ready prior to requesting delivery or plan reliability is sufficiently high that work plans can be used to predict readiness.

push vs. pull: a push system schedules the release of work based on demand, while a pull system authorizes the release of work based on system status (from Hopp and Spearman 1996 p. 317)

pushing: releasing materials, information, or directives possibly according to a plan but irrespectively of whether or not the downstream process is ready to process them.

quality assignment: assignment that meets quality criteria for release to the customer process.

quality criteria: (1) definition, (2) soundness, (3) sequence, (4) size, and (5) learning.

reasons: ...for failing to complete weekly assignments; e.g., lack of prerequisites, insufficient time, unclear directives. Reasons can also be sought for failing to advance scheduled tasks from master schedule to lookahead schedule or from one week to the next within the lookahead schedule.

resource: Labor or instrument of labor, including tools, equipment, and space. Resources have production capacities as well as costs. Consequently, materials and information are not resources, but rather what resources act on or process.

screening: Determining the status of tasks in the lookahead window relative to their constraints, and choosing to advance or retard tasks based on their constraint status and the probability of removing constraints.

sequence: Quality criterion for selecting assignments among those that are sound in priority order and in constructability order.

shielding: Not releasing work to production units because it does not meet quality criteria; the work is not a quality assignment. It is akin to 'stopping the assembly line.' The purpose of shielding is the make production units less subject to uncertainty and variation, thereby providing them with greater opportunity to be reliable.

should-can-will-did: To be effective, production management systems must tell us what we *should* do and what we *can* do, so that we can decide what we *will* do, then compare with what we *did* to improve our planning.

size: Quality criterion whereby the amount of work included in an assignment is made to match the capacity of the production unit that will do the work.

Example: Ruben and James should be able to collect that data and analyze it by Thursday. But, I forgot, it's Ruben and Tim. Tim's not as experienced as James, so I'd better give them an extra day.

sound(ness): Quality criterion for assignments that questions whether or not assignments have had all constraints removed.

Example: We never intentionally make assignments that are not sound. We always check if we have or can get necessary information from others, if the directives are clear, etc.

supplier: the provider of needed inputs: prerequisites (including materials and information), resources, directives, etc.

supplier lead time: the time from sending a request for delivery to the delivery.

task: type and amount of work assigned to a production unit.

throughput: the output rate of a production process.

underloading: making assignments to a production unit or resource within a production unit that absorbs less than 100% of its capacity. Underloading is necessary to accommodate variation in processing time or production rate, in order to assure plan reliability. Underloading is also done to release time for workers to take part in training or learning, conducting first-run studies, implementing process improvements, or for equipment to be maintained.

utilization: the percentage of a resource's capacity that is used in production.

Example 1: Because of time lost waiting for materials, our labor utilization last week was only 40%.

Example 2: We deliberately reduced next week's planned labor utilization rate so crew members could attend a training course.

weekly work plan: a list of assignments to be completed within the specified week; typically produced as near as possible to the beginning of the week.

window of reliability: how far in advance future work completions are accurately forecast.

Example: If you can accurately forecast only 1 day in advance when work will be completed, then your window of reliability is 1 day.

workable backlog: assignments that have met all quality criteria, except that some must yet satisfy the sequence criterion by prior execution of prerequisite work already scheduled. Other backlog assignments may be performed within a range of time without interfering with other tasks.

Example: Those spare parts lists don't have to be completed for 3 months, but it won't harm anything if they are produced earlier, so use them as fallback or fill-in work when needed.

work flow: the movement of information and materials through a network of production units, each of which processes them before releasing to those downstream.

work flow control: causing information or materials to move through a network of production units in a desired sequence and at a desired rate.

work-in-process (WIP): the inventory between the start and end points of a production process.

work structuring: process of breaking work into pieces, where pieces will likely be different from one production unit to the next, so as to promote flow and throughput.

APPENDIX 2: CONSTRAINTS ANALYSIS FORM

Last Planner Workbook: Performance Evaluation
www.leanconstruction.org

Project:

Prepared by:

Date Prepared:

	Responsible Party	Activity Description Remember the Five Criteria for Release of Assignments Defined - Sound - Proper Sequence - Right Size - Able to Learn	Make Ready Needs Work That Must and Can Be Performed Prior To Release of This Assignment	Period to Perform the Work							PPC Analysis	
				M	T	W	TH	F	S	Y	N	Reasons For Variance
				21	22	23	24	25	26			
1	Structural designer	Reevaluate Roof Design to support mechanical equipment	Mechanical equipment loads received	X	X	X	X			X		
2	Architect	Internal layout drawings for 2nd floor		X	X					X		
3	Architect	Reflected ceiling drawings for meeting rooms	Finalize location of access panels		X	X	X	X			X	Access panel location not finalized
4	Mechanical Engineer	HVAC drawings for 2nd floor				X	X	X		X		
5	Electrical Engineer	Lowcurrent drawings for 2nd floor	Location of CCTV cameras			X	X	X			X	Information not received
6	Landscape architect	Prepare schematic landscape design										
	Workable Backlog											
1	Architect	Furnishing drawings for first floor									X	
2												
3												
4												
5												

APPENDIX 4: WEEKLY WORK PLAN - CONSTRUCTION

Last Planner Workbook: Performance Evaluation
www.leanconstruction.org

Project:

Prepared by:

Date Prepared:

1	Responsible Party	Activity Description Remember the Five Criteria for Release of Assignments Defined - Sound - Proper Sequence - Right Size - Able to Learn	Make Ready Needs Work That Must and Can Be Performed Prior To Release of This Assignment	Period to Perform the Work							PPC Analysis	
				M	T	W	TH	F	S	Y	N	Reasons For Variance
				21	22	23	24	25	26			
1	Rebar-sub	Rebar erection for 1st floor columns 5,6,7,8	Rebar trailer on site Mon morning	X						X		
2	Electrical Sub	Electrical inserts/rough-in for 1st floor wall w1		X						X		
3	GC	Formwork for 1st floor wall w1	Sign-off of rebar inspection on Mon		X	X				X		arrived late, did not complete inspection
4	Mechanical	Builder's work or mechanical crossings in 1st floor wall w1	Coordination shop drawings		X					X		Delay in approval of coordinated dwgs
5	Electrical Sub	Electrical inserts/rough-in for columns 5,6,7,8	GI connectors		X					X		missing materials
7	GC	Formwork for 1st floor columns 5,6,7,8	Sign-off of rebar inspection			X				X		
8	GC	Pour concrete for 1st floor wall w1	Sign-off of services inspection				X			X		
9	GC	Pour concrete for 1st floor columns 5,6,7,8					X			X		Formwork not ready
10	GC	Strip formwork for columns 1,2,3,4		X								
11	GC	2nd floor Slab falsework for area 1			X	X				X		
12	GC	2nd floor Slab deck formwork for area 1				X	X	X		X		
13	Rebar-sub	2nd floor rebar installation for area 1	Deck is ready						X	X		60% done, delayed by deck formwork
14												
	Workable Backlog											
1	Rebar-sub	Rebar erection for 1st floor columns 9,10,11,12								X		
2	Electrical Sub	Electrical inserts/rough-in for columns 9,10,11,12										
3	GC	Formwork for 1st floor columns 9,10,11,12'										
4												
5												

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