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CS11526

# Production Planning and Lean Construction Explained: A Hands-on Simulation

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## Learning Objectives

In this class, you will:

1. Learn the key principles and benefits of lean construction and production planning
2. Understand the Last Planner System: breaking down the master schedule into milestone pull-plans, 6-week lookaheads, weekly work plans, and daily huddles
3. Explore the key concepts of pull planning in an interactive hands-on simulation
4. Discover how BIM 360 Plan enables a collaborative last planner approach on projects by using cloud and mobile technology

Description

You've heard about lean construction and production planning—now it's time to try it out yourself. This interactive workshop will start by addressing the problem of waste in construction and how the Last Planner System improves productivity and schedule reliability. We'll introduce pull planning: a collaborative scheduling technique that enables teams to develop workflow starting with a goal in mind and working backward, thus enabling successor activities to determine what needs to be completed for them to start their work. Then we'll put theory into practice in a hands-on, team-based construction simulation developed by DPR Construction, designed to emphasize the importance of pull versus push, reliable flow, and clear subcontractor commitments in the pull-planning process. The class will finish by showing how BIM 360 Plan software helps the last planner by enabling teams to track task commitments and completion, and report on deviations.

## Your AU Experts

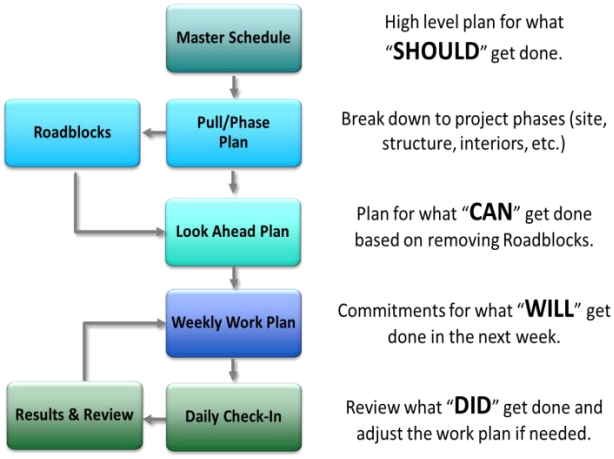
***Michael Moran*** *is a consultant at Autodesk, Inc., focusing on construction. He helps customers optimize their construction processes through adoption of cloud-based BIM 360 tools, with a focus on design review, production planning, scheduling, field management, layout, and project handover to owner/operator. His master's thesis in construction management at the Delft University of Technology was a comparative study designed to assess productivity gains from using Building Information Modeling (BIM) tools on Skanska AB U.S. building projects. Together with Skanska and Autodesk, Michael presented a webinar on this case study. Michael has taught 3 previous Autodesk University classes and has spoken multiple times about the benefits of cloud-based BIM at the European 5D Conference. Other experiences in the building industry include founding and running a concrete specialty forming firm, working as a consultant on several major infrastructure projects, and obtaining a bachelor's degree in architecture from the University of Bath in the United Kingdom.*

***Todd Elkins*** *spent 5 years developing and training lean practices for a large Bay Area-based general contractor. He was the co-creator and first employee of ourPlan, which was acquired by Autodesk, Inc., and has since been redeveloped into the new product, BIM 360 Plan web service. Todd is responsible for driving lean practices and principles into construction projects by capitalizing on technology. He is currently working with design and construction teams to transform their business processes and turn information into insight. Specialties include lean construction, construction technology, Building Information Modeling (BIM) management, strategic planning, construction management, integrated project delivery, reliable promising, last planner system (LPS), pull plan scheduling, production planning, work structuring, and production innovation.*

*Outside of DPR Construction,* ***Nathan Wood*** *is a published author and shares his experience through conference presentations at Autodesk University, Associated General Contractors (AGC) BIM Forum, Canada BIM Forum, and ThinkBIM U.K., along with international webinars with technology partners such as Tekla Corporation and Bluebeam Software, Inc.*

## Learning Objective 1: Understand the key principles and benefits of lean construction and production planning

**Lean Construction** is a combination of operational research and practical development in design and construction with an adaption of lean manufacturing principles and practices to the end-to-end design and construction process. This approach aims to manage and improve construction processes with minimum waste and maximum value by considering customer needs.




Developed by the Lean Construction Institute, the **Last Planner System**, also known as lean production planning, is a key system in the lean construction toolkit which involves requiring commitments to schedules by all project team members. The four key elements of this system shown on the left are (1) pull planning, (2) make work ready (look-ahead) planning, (3) weekly work planning and (4) daily check ins. Regular reviews of planned percent complete scores, root causes of incomplete activities and missed targets create opportunities for continuous improvement through learning.

### Documented Benefits

A 2012 literature review[1] of 26 international project-based case studies found that the Last Planner System (LPS): increased work flow reliability, improved supply chain integration, reduced project delivery or production time, improved communication among project participants, reduced firefighting or fewer day to day problems, improved quality of work practice onsite, enhanced managerial practices in construction projects, expanded knowledge and learning among project teams and reduced stress levels on construction sites . A 2013 McGraw Hill survey[2] found the results displayed on the right. Danish research[3] on project comparisons within a single company showed 65% fewer accidents and up to 70% less sickness absence on Last Planner managed construction sites.

## Learning Objective 2: Understand the Last Planner System: breaking down the master schedule into milestone pull-plans, 6-week lookaheads, weekly work plans, and daily huddles

### STEP 1 - PULL PLANNING

#### Background and origins of pull planning in construction

On most projects, schedules are prepared by professional schedulers and project managers – so called "first planners". Many assumptions are made, and slack (buffer, float, padding) is built into the schedule to compensate for any uncertainties in a detailed long term project schedule. First planners may ask members of the delivery team for expected durations and production rates if the work packages have been awarded, but delivery team members will be reluctant to give up slack when they are uncertain about whom they will be working with or what the specific conditions of the project involves. The result is that the first planner schedule is generally **pushed** on the project team. Projects are then managed in terms of what the schedule says **should** happen, without the initial buy-in and consent of the supply chain, often requiring work to be done that cannot be completed as scheduled because one or more of the flows is broken.

The concept of **pull** manufacturing was originally conceived by Taichi Ohno, father of the Toyota Production System, a major precursor of lean production philosophy and techniques. Ohno was partly inspired by visiting American supermarkets in the 1950's, where he observed customers taking the desired amount of goods off the shelf, and the store restocking the shelf with enough new product to fill up the shelf space. In this way, the shelves are only restocked with enough inventory to replace what had been withdrawn. Ohno applied this idea to Toyota factories by having a work-center that needed parts go to a 'store shelf' (the inventory storage point) for the particular part and 'buy' (withdraw) the quantity it needed. This is a key idea which enabled Toyota to achieve "Just in time" delivery of inventory, and avoid overproduction, a major source of waste in any production lines.

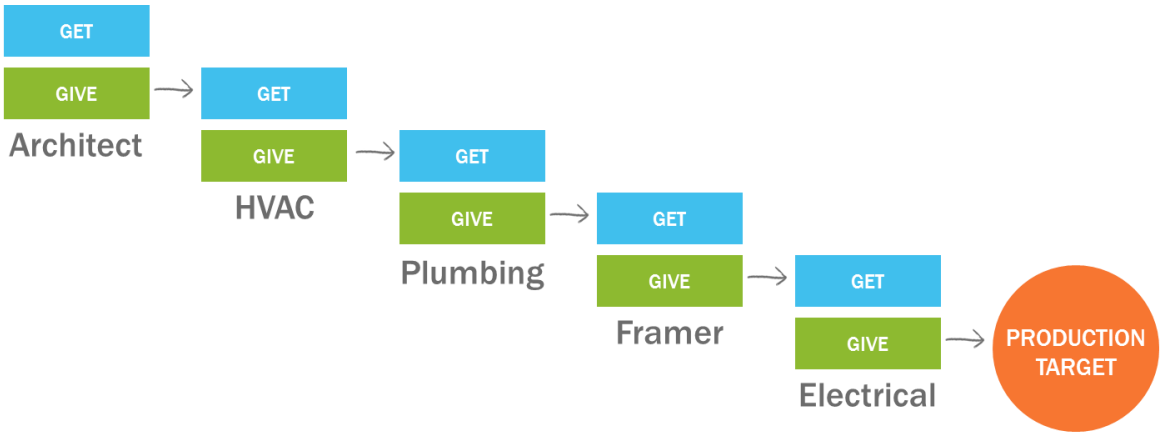
*"To produce the right product at the right time in the right quantity for the customer and to produce exactly what you need and nothing more…"*

**TAIICHI OHNO**
*creator of the Toyota Production System*

#### Pull planning concepts applied to construction

The LPS is largely influenced by the philosophy of pull manufacturing. It is a technique in construction schedule coordination and production control designed to ensure the achievement of agreed goals. Those goals are set in a collaborative scheduling process known as 'pull-planning' so that all the main suppliers and specialist contractors are engaged right from the start in developing and signing up to the master schedule and to the schedule for each phase. A phase is defined as a period of the project leading up to a major milestone, contractual or otherwise.

Pull Planning thus begins with a single milestone and works backwards in time to develop the most efficient sequence. A key concept is that everyone on a project is simultaneously both a customer and a supplier. A supplier provides what is wanted, and a customer must receive something in order to produce something which the next trade wants. In a pull-planning session, each step which needs to be completed to achieve a milestone is written on a sticky note and placed on a wall in the correct sequence. The sticky note must clearly define the list of the direct predecessors required for the step. The predecessor steps are the next sticky notes to be placed in the sequence. This process should focus on the critical hand-offs between trades and help to surface "Roadblocks" that need to be removed before the work sequence can be completed.




*A project is a network of commitments, in which each trade is simultaneously a customer and a supplier*

When all major players meet early enough in the process it's possible to discuss handoffs, interdependencies and risks, test assumptions and agree on good practice. A key task for all teams is to discover and validate customer requirements. Making time in pull planning to be clear about what team(s) want from those who precede them so that they can work more safely, faster, etc. is generally time well spent. Planning from right to left, i.e. from the future, helps build later trades' needs into the plans of earlier trades.

Sven Bertelsen, a Danish Engineer and lean construction consultant, has listed the range of uses and benefits of a collaboratively produced schedule[4]:

- A workplan of what should be done: Enables team to test options to improve workflow, constructability and program reduction. Sorts out sequencing & other issues that would be difficult to change later; issues sorted in paper-based mockup/simulation rather than at the workface.
- An organisation chart - who does what? Prepares team members for action together.
- An agreement between trades (or design teams) about when to start and finish, identifies unclear design details and allows team members discuss details much sooner.
- A logistics plan defining when we need materials, trade teams, drawings etc.
- A tool for workflow control - when we want to do which tasks.
- A basis for monitoring progress. This builds commitment to schedule and reduces overall schedule.

**Schedule compression**

When a pull plan has been agreed, it is possible to explore ways to compress it. With a supply team that had worked together on a number of similar projects previously, one UK constructor took 6 weeks out of a 20-week schedule using this approach (picture below). This clearly has enormous benefits for the owner, in this case a hotel chain: the building is earning significantly earlier. It also has benefits for the main contractor and their suppliers, they are more competitive as reducing the schedule itself reduces cost and increases profit margins. Some claim that it is generally possible to reduce schedules by about 20% by successfully adopting pull planning. One constructor showed an airport upgrade project could be delivered in 16 weeks instead of the 22 weeks that first planners thought it would take. In a subsequent workshop they managed to get that down to 12 weeks. [4]

*A project team consisting of multiple trades optimizes a schedule and discusses dependencies*

For another constructor, pull planning and schedule compression rescued a 70-week schedule that was running about six weeks late after 30 weeks. From the time of that workshop, involving all the major suppliers on the project, Last Planner was used to help keep the project on the agreed new track so that it came in on time. [4]

There are three important words in Last Planner: **"I don't know".** Admitting this is an example of "bad news early is good information". Saying that you don't know allows other people to help you fill in the gaps in your knowledge.

**STEP 2 – LOOK-AHEAD PLAN**

The Look-Ahead Plan (LAP) is not just a snapshot of the baseline master schedule. It is a more detailed breakdown of the pull-plan/phase schedule created by the Last Planners looking forward 6 weeks. The goal is to clearly define work that can be performed and to identify hand-offs between trades or workgroups. Activities are broken down in more detail as they draw closer. The 6$^{th}$ week's work is added to the LAP as the 1st week's work is committed to the Weekly Work Plan. This means the LAP is updated on a weekly basis:

- Look 6 weeks ahead to identify issues that need to be resolved to execute the plan
- Establish clear ownership for removing the roadblock with a specific timetable
- Review each week as part of extended coordination meeting or in a separate meeting
- Keep a log of all roadblocks in Plan
- Share critical roadblocks with Owner

**STEP 3 – WEEKLY WORK PLAN**

The Weekly Work Plan (WWP) is created by the Last Planners each week as the most reliable commitment of what will be done during the next week. Only "ready" work, which the Last Planners are confident can be completed within the week, should be put into this plan. Work that cannot be completed within the week should not be promised on the Weekly Work Plan. This is fundamentally different from the pull planning session, as you start with the current week and move on to the following week.

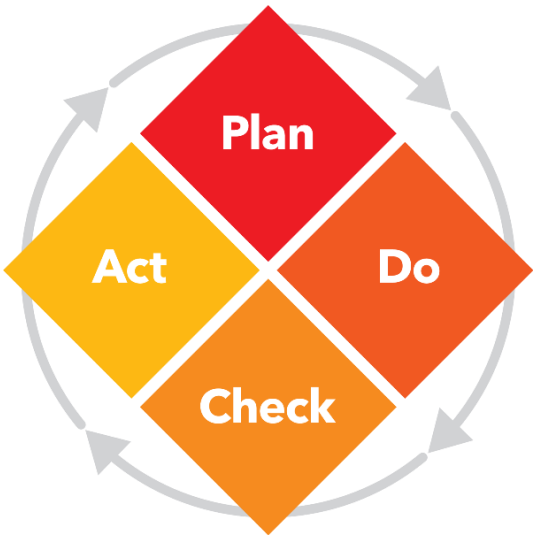
1. Meeting Preparation
    a. Target Thursdays for your weekly planning session
        i. Gives the team time to resolve any open questions and finalize the WWP by Friday
    b. Require mandatory attendance with the right people
        i. Last Planners who can make commitments for the crews in the field
    c. Set clear expectations
        i. Trade partners will come prepared with upcoming week's planned activities
        ii. Any new activities have been added into Plan before the meeting
        iii. No activity is longer than 5 days for a duration
2. Meeting Management
    a. Superintendent should facilitate the discussion
    b. Discuss Safety- 5 minutes
    c. Review results from last week- 10 minutes
        i. All committed activities have been updated
        ii. Quick review of PPC and Root Causes
    d. Finalize the production plan for next week- 35 minutes
        i. Each trade presents their plan to the rest of the group
        ii. Require explicit commitments from each stakeholder
    e. Parking Lot- Sidebar
        i. Create parking lot for items that would require extended discussion
    f. Meeting feedback and suggestions for improvement - 5 minutes
3. Post Meeting
    a. The plan is distributed to participants shortly after the meeting

**STEP 4 – DAILY CHECK-INS**

The team meets  daily to manage the WWP commitments. Participants discuss logistics, roadblocks, and update commitment status (completions or incompletions) in this daily meeting. This meeting can either occur at the beginning or end of the shift as agreed upon by the team. All trades onsite have a Last Planner present at the meeting. This meeting should last 15-20 minutes, and ideally be conducted standing –up in the field, so that the team can continue with their tasks as soon as it is completed.

**STEP 5 –REVIEW AND IMPROVEMENT**

Teams learn from their failures to complete promised work by tracking whether work is complete by the promised date, by charting the results, and by discussing them each week. Planned Percent Complete (PPC) is the percentage of work activities completed on the day they are planned. Results are reported and reviewed with the team in the WWP meeting. Reasons for incomplete activities should be recorded and the most frequent of the root causes for unreliable planning should be analyzed, with an aim of reducing future schedule variance. The team should create an action plan for improvement based off the reviewed metrics.




*Regular reviews of planned vs actual performance create opportunities for continuous improvement*

**ROLES IN PROJECT TEAM**

- **GC Superintendent(s)** - Leads the production planning process.
- **Project Engineer(s)** - Ensures documentation and thoroughness of the process.
- **Last Planners** - The last planners provide input for the production plan and manage the crews who execute the plan. Trade Superintendents and Foremen are typically the Last Planners.
- **Project Management -** Facilitate the removal of roadblocks and manages communication with the owner.

**General Contractor**

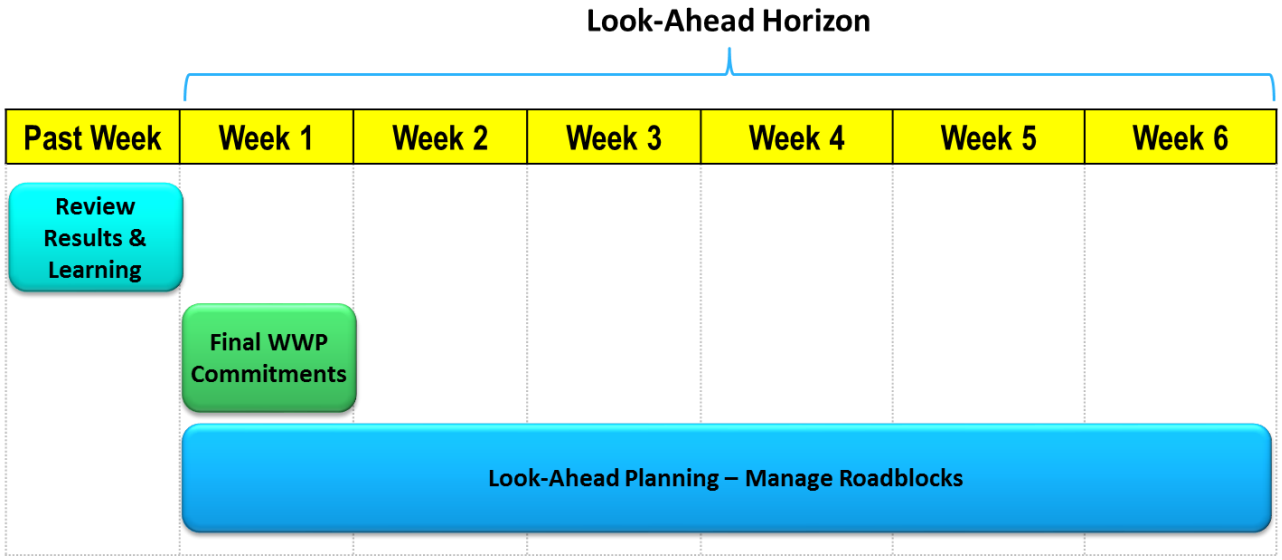
| Position | Role |
|---|---|
| Superintendent | • Reinforce and use the process to manage production in the field against the completion dates referenced in the master schedule.<br>• Lead the Pull/Phase Planning sessions<br>• Review the Look-Ahead plan submitted from trade partners<br>• Participate in daily check ins<br>• Use Plan and the process to drive production |
| Project/Field Engineer | • Capture updates and changes in the weekly coordination meeting<br>• Help trade partners use Plan to input and track the status of the weekly work plan |
| Project Management | • Work actively to help identify and remove roadblocks<br>• Manage communication with the Owner |

**Trade Partners**

| Position | Role |
|---|---|
| Last Planners | • Participate in Pull Plan Meetings as required<br>• Submit the 4 week Look-Ahead plan using the approved Excel template weekly by end of day Thursday<br>• Participate in weekly coordination meetings and make clear commitments for the weekly tasks<br>• Participate in daily check-ins and provide accurate status on the completion of commitments<br>• Use the process to drive detail into internal planning process and drive production from GF's on critical areas/systems |
| Project Management | • Provide resources needed by Last Planners to execute the plan |

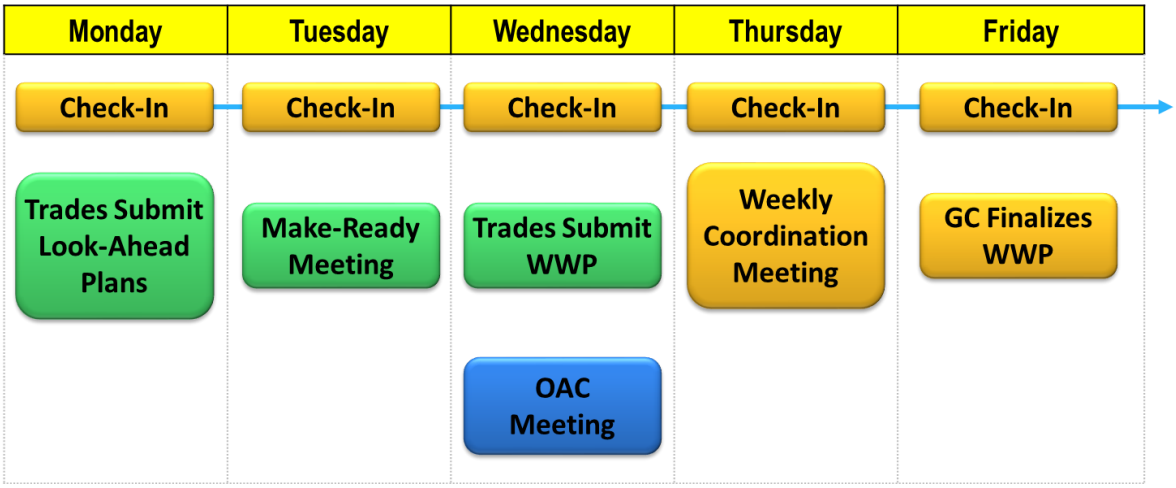
**Production Planning Horizon**

In Production Planning, teams are focused on reliable execution of the project over a short period of time. On most projects, this is a 6-week period that allows enough time to identify and remove roadblocks, without trying to plan too far in advance. Each week, the team reviews the performance from the previous week and then finalizes the Weekly Work Plan (WWP) for the week to come. Finally, the team considers the work to be done over the Look-Ahead horizon. This horizon rolls forward each week, dropping the oldest week, and adding a new, 6th week at the end.



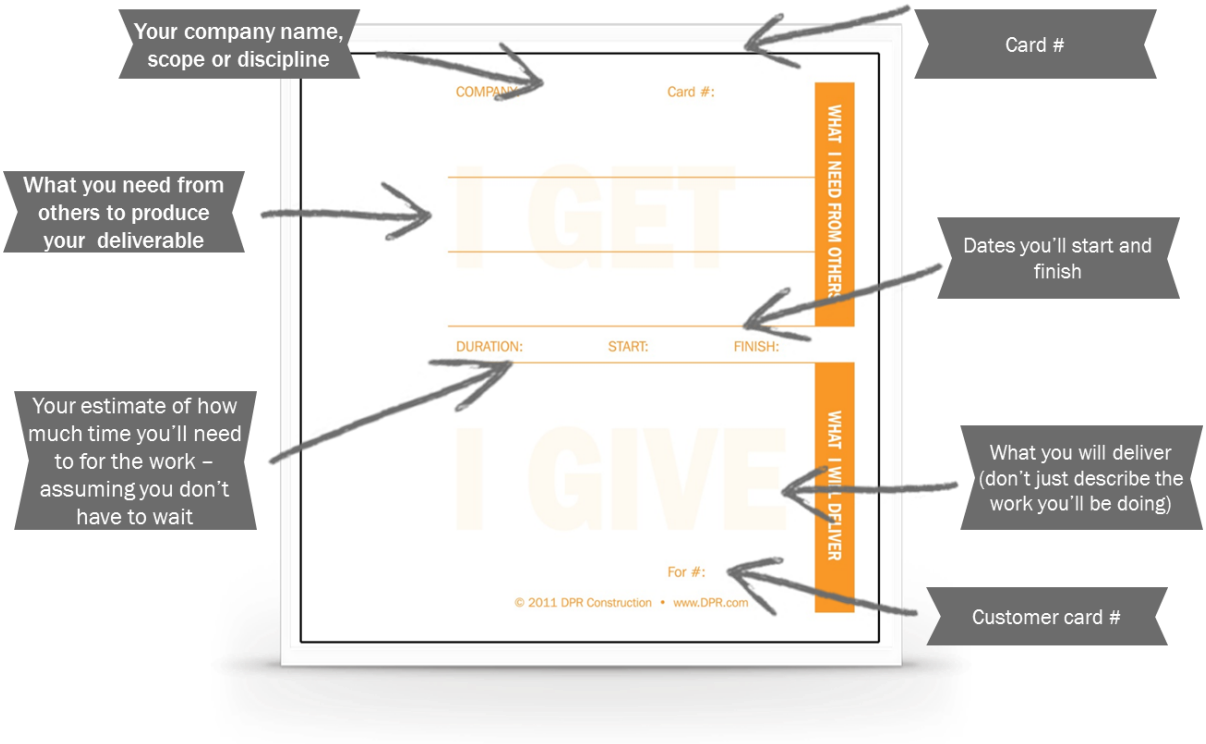

**Weekly Planning Calendar**

Production Planning uses a regular weekly schedule of meetings and activities to commit to the weekly work plans, update the status of commitments and plan the work for the Look-Ahead horizon. A typical project's weekly calendar for production planning looks like this:



## Learning Objective 3: Learn the key concepts of pull planning in an interactive hands-on simulation

During the class, our interactive simulation will involve creating a pull plan for how to build a simple structure from wood blocks. The class will be divided into teams of 8, divided into four teams of subcontractors. The teams will first work collaboratively to create pull plans using sticky notes.




*Elements of a sticky note*

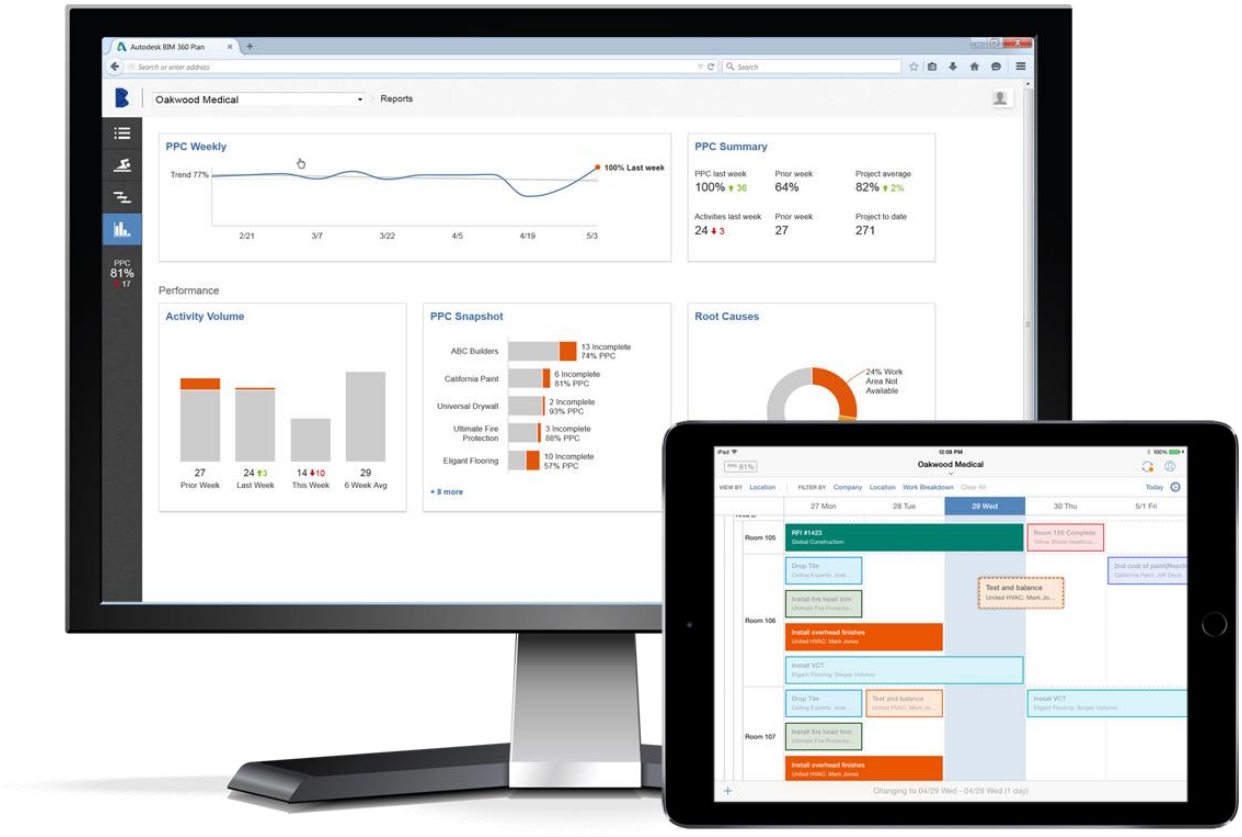
After a pull plan has been agreed on, the team will build the structure from the plan. The major objective of this exercise will be to get people to **realize that a project is a network of commitments**, in which trades make requests of one another, for example: "In order to give X I need to receive Y." A secondary realization that may come out of this simulation is that even once a pull plan is completed and agreed to by the team, there is additional production planning that needs to be done throughout the building process to optimize efficiency, reduce rework and ensure quality.

## Learning Objective 4: Discover how BIM360 Plan enables a collaborative last planner approach on projects by using cloud and mobile technology

Autodesk BIM 360 Plan is a web-based collaboration tool which supports the Last Planner System.

This software enables users to:

- Add activities into 3-6 week look-ahead plans and weekly work plans, and track roadblocks that can disrupt reliable production.
- Share a single, up to date version of the latest project work plan with the extended project team
- Reinforce Last Planner behavior with a built-in accountability and task status workflow.
- Download a snapshot of the work plan to a mobile app and work offline until back in the office.
- Edit and manage their scope of work details independently of other users, depending on access levels/permissions.
- View the same workplan in List, Gantt, or Swimlane views. Use filters to focus on specific locations, trades, and scopes of work.
- Automatically track a project's Planned Percent Complete (PPC) scores and reasons for incomplete activites with reports that help chart performance.




*View of Analytical project performance dashboards in web app and weekly workplan in iPad app*

General contractors have reported the following benefits from using BIM 360 Plan:

1. Reinforces last planner principles & encourages behavior necessary for last planner system to function correctly

2. Provides clear and automated tracking of information resulting in:

   a. Long term planning reliability improvements:

   - Provides accountability / visibility of short term schedules to other users (ie it demonstrates project manager that planners are doing their tasks and gets all crews the latest information for accurate coordination)
   - Collates root causes in one central and easy to view / review dashboard for quick feedback and learning
   - The report function provides clear graphic illustration of PPC, which encourages inter-subcontractor commitment to achieve target PPC
   - The ability to view the schedule in both Gant and Swim Lane allows visual illustrations to ensure the crews are spread / separated across the jobsite and not congested reducing potential safety hazards

   b. Efficiency gains for end users:

   - Provides an accurate, detailed as-built schedule in one form / one screen (as opposed to numerous excel as-built spread sheets)
   - Saves 1.5 - 4 hour of reporting time per week, or up to 10% of a working hours (copying, scanning, saving and storing) by automatically generating as-built schedule
   - Gives entire project team immediate access to latest version of the detailed weekly plan and 3-6 week look-ahead plan, reducing time spent looking for correct information
   - Would save many hours and provide accurate information if dates and activities needed to be reviewed in a potential future claims situation

3. Ease of use - more user friendly than excel, and it allows simple iPad viewing/updating on daily basis

4. Future potential for information connection with other scheduling and project controls applications

## References

(1) Solis et al. (2012) Survey of motivations, benefits and implementation challenges of LPS users. J Construction Engineering & Management

(2) McGraw Hill Construction (2013) Lean Construction: Leveraging Collaboration and Advanced Practices to Increase Project Efficiency

(3) Thomassen et al. (2003) Experience and results from implementing lean construction in a large Danish contracting firm. IGLC

(4) Mossman, Alan (2013) Last Planner®: 5 + 1 crucial & collaborative conversations for predictable design & construction delivery.