

## PS.1604

# Lean Construction Planning Implementation

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**Abstract**—Lean Construction Planning is an upcoming trend in the construction industry driven by Owner demands for more reliable project completions. Now Contractors and Subcontractors are finding that these Lean processes eliminate waste, achieve a more stable work flow and subsequently gain higher productivity and improved construction quality. What is Lean Construction? What is Pull Planning and how can it be implemented in conjunction with the CPM schedule to make planning and building construction projects more efficient? What are the inherent challenges and risks? How do these processes tie into the AACE® International Basic Total Cost Management® (TCM) Process Model – Plan, Do, Check, Assess (PDCA)?

In this paper, the authors' will answer these questions and discuss the implementation of Lean Construction Planning from both the Owner's and Contractors perspectives. They will describe the processes as they relate to planning and scheduling as well as lessons learned and suggested solutions in the implementation of these principles in the construction industry.

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## Introduction

The Lean process is an evolving approach to the way we plan and manage building construction projects. It is used to develop detailed short term plans by interactively engaging the cooperation of individuals who are executing the work in the field. It is not intended to replace the value of the critical path method (CPM) schedule but rather to increase the predictability of the work flow and eliminate waste. Both tools can be used simultaneously without diminishing the benefits of the other. The CPM provides the long term strategic project overview while the Lean process captures the short-interval planning and execution of the upcoming work. The result is increased collaboration, improved efficiency and unimpeded clarity in the flow of work. Other benefits of implementing Lean principles include a safer project, greater customer satisfaction, better quality work product, reduced project schedule, improved productivity, increased profitability/reduced costs, and better risk management. [1]

## Principles of Lean

“The Lean focus is to understand the difference between value and waste. To increase the value to the customer and eliminate waste.” [2] The steps involved are:

1. Define value from the customer’s perspective
2. Identify all the steps in the work process to produce customer value and eliminate steps which do not create value.
3. Make the work flow without interruptions
4. As flow is established let customer pull value from the next upstream activity. (i.e. don’t make anything until it is needed and then make it quickly)
5. Begin process again and create a culture of continuous improvement (i.e. don’t settle for good but strive for great)



**Figure 1 – Principles of Lean**

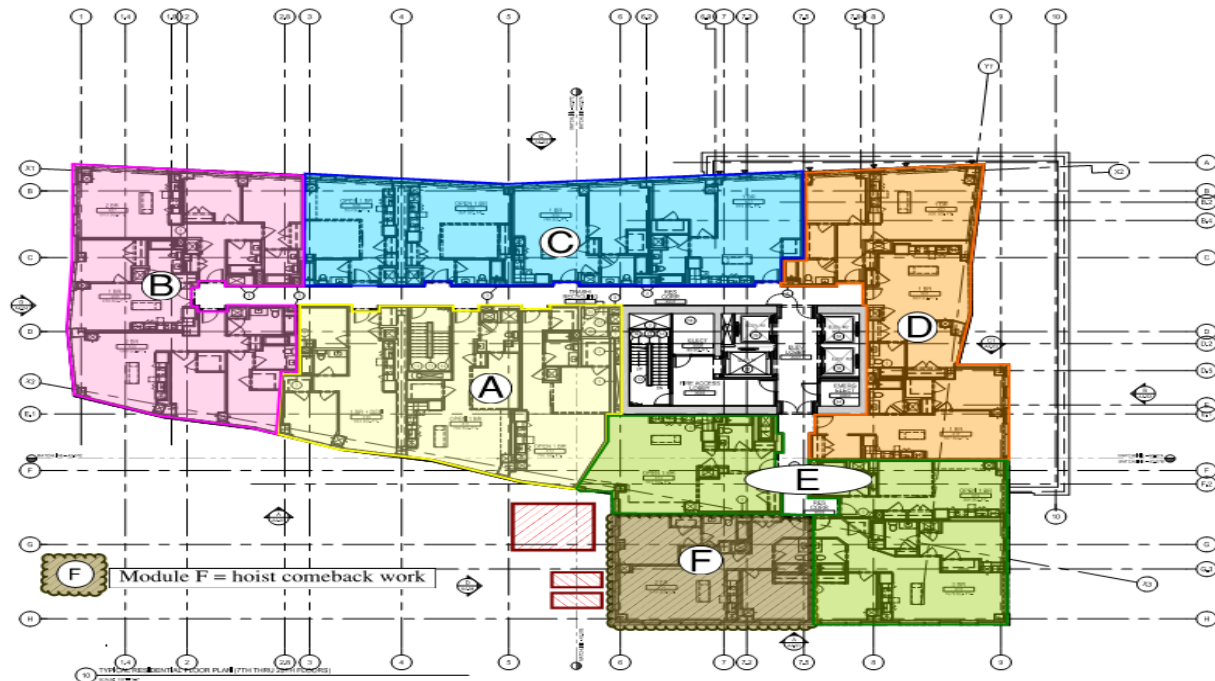
## **The Lean Planning and Scheduling Process**

The Lean process focuses on the efficient use of labor and materials by creating a work flow and eliminating waste. The traditional scheduling process focuses on durations and task relationships to find the minimum time or “critical path” to complete the project. In a Lean construction environment the goal is to eliminate the bottlenecks that can occur in traditional projects by focusing on the overall goal of the project and not the individual tasks.

The Lean Construction Institute developed and registered the Last Planner System® (LPS) as a tool to aid in Lean Planning and Scheduling process. [3] The process involves five key steps: module diagram development, Phase Pull Planning, 6-week Make Ready Planning, Weekly Work Planning, and Continuous Learning.

Kick off training: To kick off the Lean planning and scheduling process, it is important to hold a meeting with the project stakeholders (i.e. superintendents, project managers, subcontractors and owner and design team). Topics of discussion should include a broad overview of the Principles of Lean as well as a detailed explanation of Lean Construction and the Pull Planning Process. At the conclusion of the kick off meeting the next meeting is set up to develop the pull planning schedule for a particular phase of work.

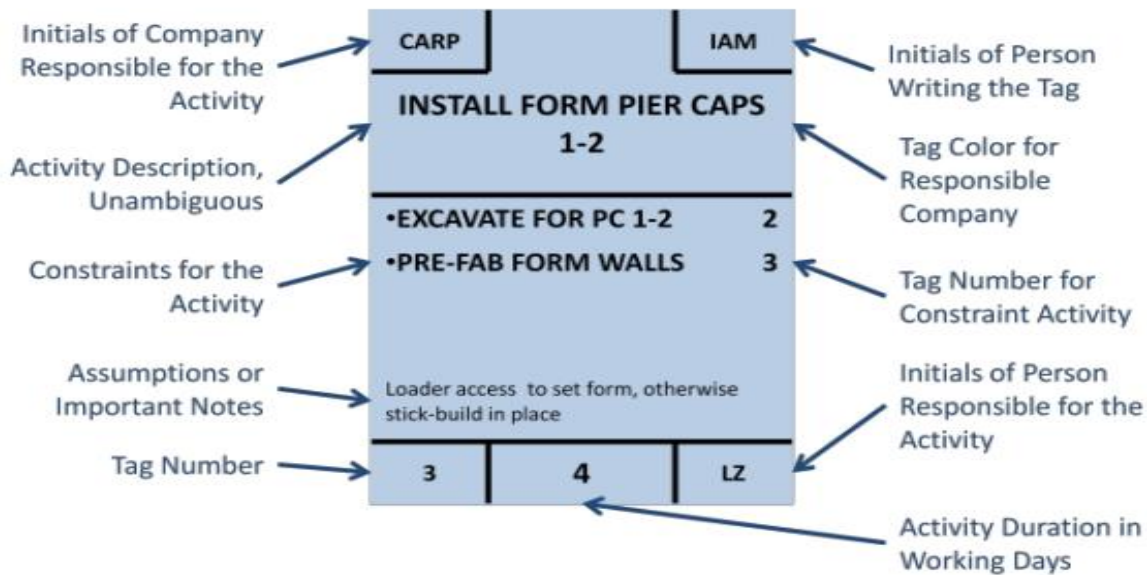
Module Diagram Development: The Superintendent develops a module diagram(s) prior to the pull planning session. The modules are structured to break down the work into manageable pieces or areas of work. Work tasks within a module will have a maximum duration from one to three days for optimum work flow. The goal is to allow smooth and stabilized crew flow through the area or floor. An example of a module diagram is found below where the colors identify the separate modules on a building floor plate:



**Figure 2 – Example of a Module Diagram for a Building Floor**

Phase Pull Planning Process: All the team members responsible to execute a specific phase of work will participate in developing the Phase Pull Plan (PPS). This is prepared by the team actually responsible for doing the work (usually the trade foreman) and facilitated by either a project team member or consultant if the team is new to the process. The PPS should be developed in a face-to-face conversation that establishes context, defines the deliverables (the client value), develops an execution strategy, identifies tasks and organizes them in a pulling plan working from the end of the phase back to the beginning. All trades required for delivery of the phase must attend the session. Each trade is provided with colored post-it notes and assigned a different color.

Work items must produce a deliverable defined in terms accepted by the customer. In this case, “customer” is the next trade in the flow of work. Teams (trades) list task descriptions, location, duration, and crew size on their post-it notes. Tasks should be limited to no greater than three days in duration; therefore the teams need to consider increasing crew size if the duration is larger than three days. The description of the work item should be specific; rather than just “frame walls” the description should indicate which specific walls will be framed.



**Figure 3 – Pull Plan Post-it Note Example**

The pull planning process starts with completion milestone of the phase of work from the project Critical Path Method (CPM) schedule. Teams work backwards posting the tasks on a wall or Pull Planning Board and work collaboratively to post their tasks in sequence horizontally from right to left. Teams agree on the hand-off criteria between tasks. Notes posted vertically indicate concurrent tasks. An attempt should be made to establish a work pace that allows each trade to plan their staffing. A steady pace across the phase coupled with the reliable completion of work tasks will produce flow.

The phase pull plan created by the teams generally consists of a single module. The full Pull Plan is then captured in either a spreadsheet or scheduling software. The full pull plan extends the work flow to show all modules for the specific phase and the staggered start between modules to ultimately determine the total flow and duration of the phase. The phase pull plan is checked to ensure that it fits within the parameters of the project Baseline Schedule. The desired objective is that the pull plan dates are better than what is in the Baseline Schedule but certainly not later. This full pull plan is then used to create 6-week Make Ready Plans and Weekly Work Plans.

Rolling 6-week Make Ready Plans: The 6-week Make Ready Plan (MRP) is derived from the Phase Pull Plan. The tool is a document that tracks all of the constraints to getting work complete in a look ahead format. A constraint is anything that will prevent a task from starting or finishing as scheduled except prerequisite work. Typical constraints included on the look ahead are material procurement, Request for Information (RFI) answers required and other answers needed to make sure the work can flow uninterrupted.

In order for the 6-week Make ready plan to be an effective tool, all parties must be involved in the process. Trade Contractors identify constraints in advance of when work is to be done and don't start work that can't be finished because of known unresolved constraints. Superintendents review the constraint log to ensure trades are doing adequate make ready planning and take appropriate planning action when constraints are not removed as needed by project. Project Managers and Project Engineers manage the constraint process including the constraint log and obtain reliable commitments from performers for removal of constraints. The Architect, Engineer, and Owner make and keep reliable commitments to remove constraints for which they are the performer.

Managing Constraints: For Week 1, ensure all tasks scheduled for this week are free and clear of constraints. If the constraints cannot be removed in time for the tasks to proceed free and clear, then determine a work-around plan and move the constrained work to a subsequent work week. For Weeks 2 through 5, review tasks scheduled for these weeks to validate or update information and determine and monitor the plan for eliminating constraints. Constraints should be well on their way for removal in this time-frame. For Week 6, review the tasks that are beginning and determine the constraints that could affect the work. This includes reviewing the plans, specifications, other construction documents such as submittals, RFIs and change documents. Determine if there is any missing information or dimensional clashes that would create a constraint for the Week 6 work. Review if there is any special equipment and/or labor required and facilitate the process of procuring the necessary resources. Determine the status of submittals, approvals and material deliveries to support the tasks. Identify deliveries that need to be closely monitored in the upcoming weeks. Don't forget to review any special safety concerns and permitting issues that could develop into a constraint.



**Figure 4 – Six Week Look Ahead Make Ready Plan**

Weekly Work Plan (WWP): All work items in the Weekly Work Plan (WWP) should be derived from the 6 Week Make Ready Plan and linked to the Pull Plan. The WWP contains only work items that are ready to be performed. Only tasks in a condition to start and finish on time should be included in the WWP. Assignments on the WWP should be sized for daily completion. The Lean principle of small batch production should be followed whenever possible. Inspection tasks should be included in the WWP. Workable backlog should also be included in the WWP.

A Weekly Work Plan meeting is held to discuss the planned work for the week, safety precautions, quality concerns, just in time material transport and location within the building, manpower allocation and availability, construction methods, and backlog of ready work. The meeting promotes a two-way conversation to share information on a project in an efficient and accurate way. The meeting determines if planned work has all the proper resources so that it can be done and only commits to performing tasks that can be done which eliminates a major source of variation in performance and productivity thus making the ability to predict completion easier. As the work is stabilized, the team can predict when work will be available more in advance and productivity improves.



A Daily Commitment Management meeting is held at the end of the day in the field and is attended by area superintendent or someone acting in that capacity. The Weekly Work Plan is reviewed to determine if tasks were completed as promised. Subcontractors report “Done”, “Not done” or “Done but not according to plan” and why. Items of discussion include: What modifications should be made in the future? How does the team prevent reoccurrence? Should the team modify the plan? In this meeting Subcontractors recommit to the coming day’s work or renegotiate a new promise.

**Performance Measurements:** Built into the Pull Planning process is a tool that tracks the reliability of commitments by each subcontractor. Each project tracks the Plan Percent Complete (PPC) of the Pull Plan. The metric tracks the percent of commitments made over the total number of commitments. These percentages are then published in the meeting room for each team member to see and be held accountable to.

Plan Percent Complete (PPC) Metric:

Planned Percent Complete (PPC) = # of tasks completed / # of tasks planned for completion

To be counted as complete, the task must be 100% complete. Reasons for non-completion are compiled, reviewed and actions taken to prevent recurrence. The following is an example of PPC measurements:

#ers to date	Exterior				Interior		
	182	124	68%		265	245	92%
Day	# activities	# complete	% complete		# activities	# complete	% complete
5-Nov	2	2	100%		5	5	100%
6-Nov	2	2	100%		6	4	67%
7-Nov	2	2	100%		6	4	67%
8-Nov	1	1	100%		4	4	100%
9-Nov	3	1	33%		3	3	100%
10-Nov							
11-Nov							
12-Nov	4	2	50%		6	6	100%
13-Nov	6	4	67%		7	6	86%
14-Nov	5	2	40%		10	9	90%
15-Nov	4	3	75%		6	6	100%
16-Nov	5	3	60%		9	8	89%
17-Nov							
18-Nov							
19-Nov	8	4	50%		6	6	100%
20-Nov	11	5	45%		5	4	80%
21-Nov	6	2	33%		4	4	100%
22-Nov							
23-Nov	2	0	0%		1	0	0%
24-Nov							
25-Nov							
26-Nov	6	2	33%		8	8	100%
27-Nov	5	4	80%		10	8	80%
28-Nov	9	8	89%		9	8	89%
29-Nov	6	4	67%		9	8	89%
30-Nov	5	2	40%		8	8	100%

**Figure 5 – Planned Percent Complete (PPC) Example**

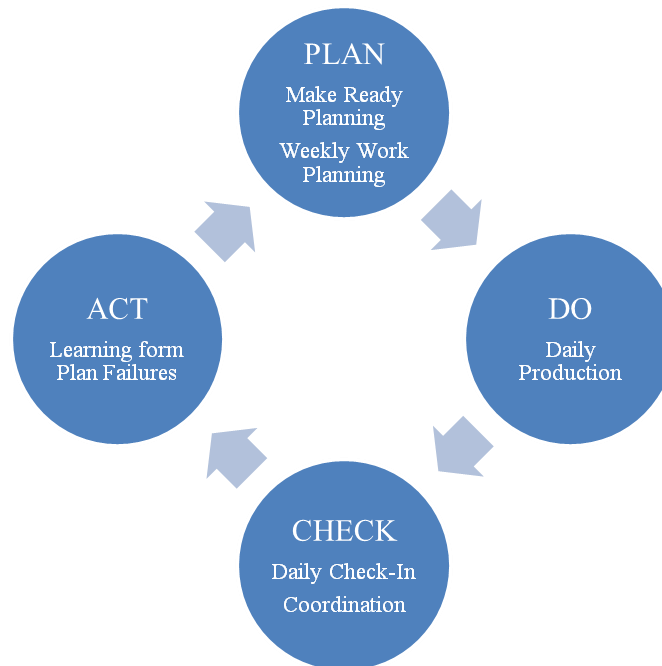
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Teams can get to 70% PPC without much trouble. High reliability (above 85% and increasing) is the goal. The difference in a day on the project will be quite noticeable: firefighting will drop by about 40%, work will flow, crews will get ahead of schedule, and safety incidents will disappear. It has been found that “projects using LPS have demonstrated a planning reliability (PR) of 85%; compare that to traditional projects where PR is around 50%.” [4]

Continuous Learning: Lessons Learned is a key tool in the Lean process. There is a continual cycle of Plan – Do – Check – Act (PDCA) similar to the AACE® International Basic Total Cost Management ® (TCM) Process Model – Plan, Do, Check, Assess (PDCA). [5] As in any manufacturing process, it is important to take what is working and find ways to make it more efficient and it is just as important to take what is not working and eliminate it from the process.



**Figure 6 – Plan-Do-Check-Act (PDCA) Cycle**

### **Lean Planning Case Study – Residence Hall Project**

Lean principles were applied to the interior finish construction of a 21-story university residence hall which is the first Lean project in Boston, Massachusetts. The senior superintendent who was once a skeptic of the Lean planning principles now promotes the planning system after implementing it on the project.

The project had a traditional detailed Critical Path Method (CPM) schedule which was created by the project team and accepted by the project stakeholders. It was subsequently updated on a monthly basis. The Lean planning process was not implemented until one month before the start of the interior building finishes. The project team created a module diagram that would establish a reliable work flow on each floor. The floor plate was approximately 7250 square feet. In this case the floor was split up into two modules, with four rooms in each module. One





**Figure 8 – Pull Plan Schedule for the Residence Hall Project**

In reviewing the as-built information, the actual durations to finish a floor started out at 13.8 weeks and continued to improve to finish in 8 weeks. It took several floors to get the floor sequence stabilized to obtain a reliable flow. The constraints that initially affected the flow were the delivery of materials and priority of hoist usage to get the materials efficiently to their floor destination. In applying the Lean principles, the subcontractors were not permitted to store materials on a floor since it obstructed the workflow. Materials were delivered to the site and brought up the hoist on a just in time basis.

A tabular and graphical representation of the baseline schedule plan and the actual dates using the Lean planning methodology is as follows:

**Lean Analysis for Mass Art Project**

Floors	Schedule Just Prior to Start of Drywall			As-Built Schedule - Unit FinishesLean Process		
	Planned Drywall Start	Planned Finish Units	Planned Dur	Actual Start Drywall	Actual Finish Units	Actual Dur
Floor 4	29-Jun-11	1-Sep-11	64	29-Jun-11	4-Oct-11	97
Floor 5	7-Jul-11	9-Sep-11	64	7-Jul-11	4-Oct-11	89
Floor 6	14-Jul-11	16-Sep-11	64	12-Jul-11	4-Oct-11	84
Floor 7	21-Jul-11	23-Sep-11	64	18-Jul-11	6-Oct-11	80
Floor 8	28-Jul-11	30-Sep-11	64	21-Jul-11	17-Oct-11	88
Floor 9	4-Aug-11	7-Oct-11	64	25-Jul-11	21-Oct-11	88
Floor 10	11-Aug-11	17-Oct-11	67	1-Aug-11	25-Oct-11	85
Floor 11	18-Aug-11	24-Oct-11	67	5-Aug-11	26-Oct-11	82
Floor 12	25-Aug-11	31-Oct-11	67	11-Aug-11	27-Oct-11	77
Floor 13	1-Sep-11	7-Nov-11	67	18-Aug-11	31-Oct-11	74
Floor 14	9-Sep-11	15-Nov-11	67	24-Aug-11	7-Nov-11	75
Floor 15	16-Sep-11	22-Nov-11	67	31-Aug-11	10-Nov-11	71
Floor 16	23-Sep-11	30-Nov-11	68	8-Sep-11	15-Nov-11	68
Floor 17	30-Sep-11	7-Dec-11	68	13-Sep-11	16-Nov-11	64
Floor 18	7-Oct-11	14-Dec-11	68	19-Sep-11	17-Nov-11	59
Floor 19	17-Oct-11	21-Dec-11	65	22-Sep-11	22-Nov-11	61
Floor 20	29-Oct-11	29-Dec-11	61	28-Sep-11	23-Nov-11	56

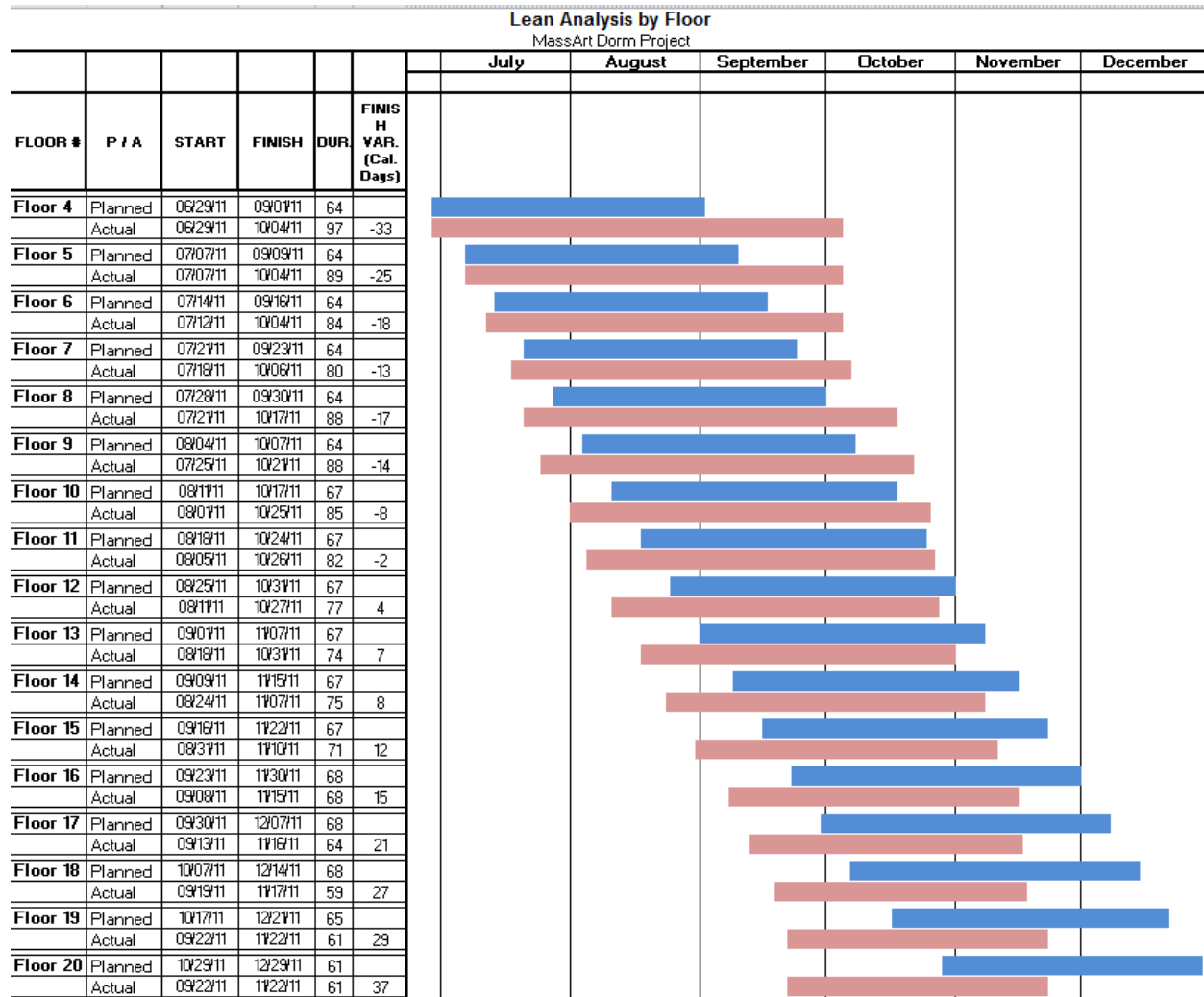


Figure 9 – Lean Analysis for the Residence Hall Project

### Challenges of Implementing Lean Planning with Traditional Scheduling

Some obstacles associated with the implementation of Lean Planning in the construction industry that is ingrained in traditional planning methods:

- Culture Change. Lean is a complete shift in the way of doing business as usual in the construction industry. Construction has always been about “pushing” the trades through the use of a Critical Path Method schedule developed by the General Contractor with little or no input from the trades responsible for the work. The Lean process involves “pulling” from the trades, giving them responsibility to develop the plan together along with the General Contractor, and holding all team members accountable for meeting the plan.
- Lack of knowledge, training, and experience for all levels of the team. Because the Lean process is such a new approach to construction planning, there will inevitably be some

roadblocks when the process is first introduced. In the typically conservative construction climate, there may be some initial fear in losing planning control for the superintendents and project managers used to the traditional planning methods. Lean planning tools can also be a hard sell for subcontractors that have been accustomed to working on the same schedules for years. Once they begin implementing the lean concepts into their planning approach, they begin to see and understand the benefits.

- Lack of commitment from all levels of the team (from trade foreman to executives)
- Lack of accountability
- Contracts and specifications which are not suited for the implementation of Lean planning process. Typically the Contractor must develop a detailed Baseline CPM Schedule early on which meets contract and scheduling specification requirements. With tight deadlines for submission of this schedule for approval, there is not enough time to involve all the trade contractors in the development of the schedule. Therefore when the trades are brought on board and become involved in the pull planning sessions the “detail” of the schedule changes. This can become an issue dependent on how the scheduler handles the incorporation of the pull plan sessions into the detailed contract CPM schedule. Worst case the Scheduler deletes all the activities that were in the Baseline schedule and effectively re-creates a new schedule each time a pull planning session is held. This causes problems for all parties when trying to evaluate progress and analyze impacts compared to the original Contract Baseline schedule and past monthly progress updates.
- Coordination between the CPM contract schedule and Lean planning schedules. Milestones established in the Baseline CPM schedule are used to create the Lean planning schedule. The Lean sequences must fit within the controls set up within the Baseline CPM schedule. There is still a need for a detailed baseline schedule to establish the duration and sequencing for a project, especially in the case of Guaranteed Maximum Price (GMP) and lump sum contracts. The Lean schedule is only a portion or phase of the CPM schedule. It is rather a more detailed schedule through the collaboration of the project stakeholders. The Lean planning schedule needs to be checked against the Baseline CPM schedule to ensure that the expectations of the contract are met or improved. It is intended to be far more detailed than the CPM schedule. Many CPM scheduling specifications require the activity durations to be less than 15 workdays whereas the Lean planning durations should be less than three days. CPM schedules allow start to start and finish to finish relationships with lags however the Lean planning schedule only permits the use of finish to start relationships. Finally the CPM concept of total float is not applicable in the Lean planning schedules simply because they are only fragments of the CPM network. The Lean schedules are managed by the commitments made to the dates and workflows rather than the actual mathematical equations that are established in the CPM.

Other challenges in the implementation of Lean include lack of sufficient support across the project team, perception that Lean is too complex, employee resistance, lack of industry support / understanding of Lean, perception that Lean will take up too much time, lack of standards, concerns about profitability through the transition to Lean, and union resistance. [1]

## Lean Implementation Lessons Learned

Suggestions on the successful implementation of the Lean process include:

- **Commitment:** A company just starting out in the implementation of Lean needs commitment from the executive level to provide the resources needed for the implementation and willingness to change the traditional way of doing business.
- **Champions:** There must be champions within the organization to implement the Lean principles. “Whether it was a top-down or bottom-up approach to initiating the pursuit of Lean, all contractors generally recognize that field workers need to champion the cause for it to be effective.” [1]
- **Training:** A key to the successful implementation of the Lean process is training all team members in the key principles and steps of the Lean planning and scheduling process. It is extremely helpful to hire a consultant experienced in the Lean process to provide training and assist in facilitating pull planning sessions until the team itself gains more experience.
- **Accountability:** All team members must be held accountable for their role in the Lean process.
- **Contracts:** Lean is well suited for Integrated Project Delivery (IPD) and Design-Build projects where many members of the team are brought together early on in the project. If the Owner wants the Contractor to use the Lean process on a project it should be stated in the Request for Proposal, contract and specifications. If the General Contractor intends to use Lean principles on the project, it should also be stated in the Instructions to Bidders and Subcontractor Agreements.
- **Coordination between the Contract CPM Schedule and the Lean schedules:** The CPM Schedule should be the basis for developing the pull plans. As mentioned earlier, the pull planning process starts with completion milestone of the phase of work from the project Baseline Schedule. The pull plans are the basis for developing the 6-week Make Ready Plans. The 6-week Make ready plans are the basis for developing the Weekly Work Plans. Each of these documents must be coordinated with each other.

## Conclusion

The Lean process is an evolving approach to the way we plan and manage building construction projects. The Lean Planning tools, including module diagram development, Phase Pull Plans, 6-week Make Ready Plans, and Weekly Work Plans are used in conjunction with the CPM schedule to make the installation of the work more predictable and reliable with less waste. Lean performance metrics using Planned Percent Complete are simple but effective in generating continuous improvement with project subcontractors. The implementation of Lean Planning on pilot projects has shown increased collaboration between subcontractors, improved efficiency in performing their work, and improved predictability in completing the work as planned. The lean process has created a new mindset and culture with lean planning



principles. Similar to the case study mentioned above, teams implementing Lean principles have shaved weeks off their schedules. “We learned we can deliver projects much faster if the right people are involved with planning at the right level of detail at the right time – all it requires is a change in the way we plan and how we communicate it.”[6]

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