

The Last Planner® System in an Experiential Construction Management Lab

Bradley A. Hyatt, P.E., LEED AP
California State University, Fresno
Fresno, CA

Lean construction is a fast growing trend in the construction industry. The promise of lean construction is the project team's ability to deliver projects more efficiently and with better overall results. Because of the rapid growth of this trend, lean construction has yet to be integrated into undergraduate construction curriculum. The Fresno State Construction Management Program incorporated the Last Planner® System into a senior level construction project controls lab. The Last Planner® System (LPS) is a production control system based upon the theory and core concepts of lean construction. Student teams used LPS to manage the construction of a simple, wood frame building over the course of a semester. The additions of consistent instructions, a 'visual control board', and a focus on daily application improved consistent use of LPS during the semester.

Key Words: Lean Construction, Last Planner System, Undergraduate Construction Education, Experiential Learning

Introduction

Lean production management focuses on 'maximizing value while minimizing waste' as established in the Toyota Production System over a half century ago (Liker, 2004). As applied to construction, producing value while eliminating waste supports an approach focused on delivering superior projects in a timely and cost effective manner. Ultimately, lean construction strives to eliminate the inefficiencies that commonly plague construction projects (Howell et al., 2011). A recent paper by Forbes, Ahmed, Yaris, and Batie (2014) stated, "Lean construction addresses that shortcoming by applying weekly (and sometimes daily) measurements, using the lessons learned in the next week and not just in the next project."

Lean Construction is a fast growing trend in the industry. The McGraw-Hill 2013 Smart Market Report provided an update on the acceptance, benefits, and common practices of lean construction. The report noted, "When only considering the responses of the contractor panel, which is representative of the industry, 37% are not familiar with any Lean practice". This suggests that more and more construction organizations are familiar with the benefits of lean construction. However the depth of knowledge (47% of lean practitioners) and industry understanding of lean construction (39% of non-practitioners) are the identified as the primary challenges for adoption. The report also identified education as the primary method to increase adoption.

The growth of lean construction practices is also seen in those firms that hire construction program graduates. A recent review of the Fresno State Construction Management Program's list of prior year graduates revealed that over half of the students were placed with firms that documented use of lean construction on their projects. This led the program faculty to find creative ways to add lean construction into it's curriculum.

Lean Construction in Undergraduate Education

Because lean construction is an emerging industry trend, very few construction education programs incorporate these topics into their curriculum (Forbes et al., 2014). Even fewer undergraduate programs include lean construction in their courses. And a majority of these courses are taught as electives. Regardless, lean construction scholars argue that all construction education programs should provide courses that teach students how to design production systems (Howell, 2011).

The Construction Management Program at Fresno State has been teaching lean construction topics in a junior level construction scheduling course for over five years (Hyatt, 2011). The impact has been graduates that are not only familiar with lean construction practices, but also the key concepts and theory underlying these practices.

A good example is students' familiarity with 'pull planning'. The McGraw-Hill report (2013) noted that pull planning is one of the most popular lean practices utilized in the industry. Students in this scheduling course participate in a mock pull planning exercise (Hyatt, 2011). Therefore, when they see the practice used on an actual project they understand the core concepts and benefits of pull planning.

The remainder of this paper describes the further implementation of lean construction into the follow on class, construction project controls (CPC). The CPC course uses the Last Planner® System to manage a small, hands on project in the lab portion of the class.

The Last Planner® System

The Last Planner® System (LPS) is a production control system based upon lean construction concepts. LPS is built on a system of connected conversations that move a team from what they 'Should Do' to learn from what they 'Did' (see Figure 1). This system is also unique because it places a bulk of the planning on the 'last planners' instead of 'first planners'. 'Last planners' are those team members that manage at the 'face of the work' compared to 'first planners', which are removed from the day-to-day management of the work. Traditionally 'last planners' are the front line supervisors compared to 'first planners' which are typically project managers. (Ballard, 2000)

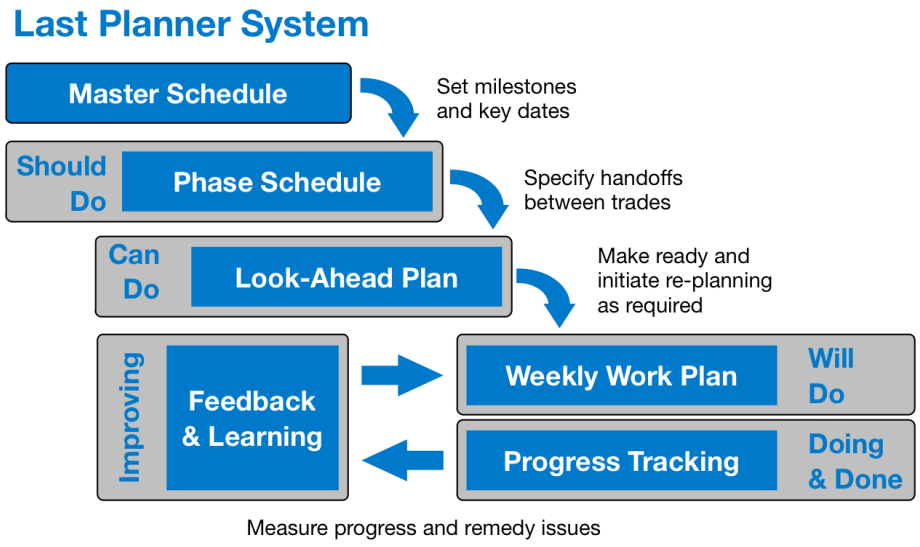

Figure 1: Last Planner® System Flowchart (Smith, 2011)

The Lean Construction Institute (2014) lists the five elements of LPS as: (1) Master Scheduling, (2) Phase "Pull" Planning, (3) Make Work Ready Planning, (4) Weekly Work Planning, and (5) Learning. The following paragraphs will briefly describe each of these elements.

Element 1 - Master Scheduling: The purpose of 'Master Scheduling' is to validate the overall project time frame as established by the contract. This allows the project team to also identify major milestones, long lead items, and significant phases of the project. A basic milestone schedule is created at this time. Note that this portion of LPS is the only one that the 'first planners' (i.e., project managers, schedulers, etc.) are the ***primary participants***.

Element 2 - Phase "Pull Planning": 'Phase Planning' allows the project team to establish a more detailed schedule for each major phase of the project. The 'last planners' collaboratively create a phase schedule using the 'pull' method. The pull scheduling method requires the team to work backwards from the final milestone of the subject project phase. The highlight of the pull method is to focus on conversations between trades with the goal to identify the key 'hand offs' between the trades. 'Hand offs' allow these last planners to better understand what they need completed by other trades prior to starting their own work. The last planners are then able to clearly discuss these requirements with each other.

Element 3 - Make Work Ready Planning: 'Make Work Ready Planning' focuses on looking several weeks ahead and identifying any constraints that would keep planned work from starting as scheduled. The two primary tools used in this element are a look ahead plan (LAP) and a constraints log. The LAP can be built upon the activities identified in the 'phase pull plan'. The constraints log is a list of any issues that are currently keeping an activity from beginning. Once all constraints have been removed, then the activity is 'made ready'. Review of the LAP and constraints log typically occurs during the 'Weekly Work Planning' meeting.

Element 4 - Weekly Work Planning: A cornerstone of LPS is the idea to collaboratively plan, review, learn, and re-plan tasks at the production level. This occurs during the 'Weekly Work Planning' meeting. This meeting requires the last planners to review the previous week's work, learn from variances, discuss upcoming work (Make Work Ready Planning), and plan for the next week. The 'Weekly Work Plan' (WWP) identifies all of the activities for planned for that week. This encourages all last planners to collaboratively plan on a weekly basis.

Element 5 – Learning: The final element of LPS is learning. This takes place during the WWP meeting and includes reviewing planned work from the previous week's WWP and learning from the failures of that plan. The first tool used to learn from failures is the Percent Planned Complete (PPC) log. PPC is simply the number of activities completed divided by the total activities planned for that week. Tracking this percentage on a week-to-week basis provides a snapshot on how well the team is planning and executing work. The second tool used to learn from failures is the variance log. The variance log tracks reasons that activities were not completed as planned in the WWP. The overall variances are often shown on a Pareto chart to allow teams to identify the most common failures. This provides data to continually learn from failures and to better plan future activities.

A Note on Experiential Learning

A recent review of lean construction in construction education noted, "Lean educators are moving away from traditional course delivery methods that focus primarily on lectures and testing to more interactive methods that promote critical thinking and discussion between educators and students" (Taos et al., 2013). Additionally, some construction education programs have started to move toward interactive lab activities to teach key construction management skills (Korman, 2013; Tingerthal, 2013). These examples support the idea that experiential learning is an excellent mechanism for students to apply knowledge and skills introduced in prior courses (Kolb, 1997).

The preceding construction scheduling course (Hyatt, 2011) presents the cores concepts of lean construction by using various simulations that are common in other lean construction courses (Taos et al., 2013). Thus, students have already been introduced to lean principles and the Last Planner® System before beginning this project controls course. At this point, students can focus on applying the skills and abilities required to effectively implement LPS on the lab project.

The Construction Project Controls Course

The Construction Project Controls course at Fresno State incorporates three broad topics: project management, project accounting, and construction business management. The course meets for two lecture hours and three laboratory hours each week. The lecture period included all three topics, while the lab covers the first two topics. The lab period requires teams of 4-6 students to build and manage a small, hands-on project throughout the semester. The lab is broken down into four phases: bid, pre-construction, construction, and close out.

The ***bid phase*** is one lab period in length and requires student teams to submit a bid (i.e., cost estimate) to complete the project. The project is 'procured' via a low bid, stipulated sum contracting process. The purpose of this phase is to simulate the speed of the bid process and to provide a basis for detailed planning in the next phase. It should be noted that the student teams have 2 hours and 30 minutes to submit their bids. The remaining 20 minutes of the lab period is used as 'bid opening' and a brief evaluation of the submitted bids.

The three-week ***pre-construction phase*** requires students to create an initial plan for the project. Student teams create a series of detailed planning documents. The purpose of this phase is to allow students to better understand all of the project scopes of work. During this phase teams create detailed scopes of work and set up systems for project administration, cost control, and production control. The phase culminates with a pre-construction presentation that simulates a project team's presentation to their 'company executives' in which they demonstrate their collective understanding of the project.

The ***construction phase*** covers a majority of the semester (approximately 10 or 11 periods depending on the semester). Student teams are required to build and manage construction of the project during this phase. The primary purpose of this phase is to ***manage the project***. A secondary purpose of the phase is to provide students with a further understanding of means and methods of the project. Each student rotates through three or four management roles. These roles include project manager, project engineer (optional), quality/safety manager, and superintendent. It should be noted that the superintendent role is the point person for most of the LPS activities in the lab. This simulates the role of the superintendent as the main coordinator of LPS as in practice.

The final phase is ***close out***, which requires the teams to submit all final payments and other close out documents. This phase takes place during the final lab period of the semester. The primary purpose of this phase is to remind students that the project is not fully complete until all documents are finalized and accepted by the owner. The instructor also takes the final portion of the lab period to conduct a "plus/delta" exercise. This exercise allows students to provide feedback on what went well (plus) and what could be changed for the future (delta). This embodies lean construction practice of 'continuous learning'.

The Project

The lab project typically requires student teams to build a small, wood frame building. This makes the project simple enough that student teams can complete the project in approximately 30 contact hours (10 weeks at 3 hours per week). Yet, the instructor can further challenge students by adjusting project plans as desired.

As previously highlighted, the primary focus of the lab is to have student teams manage the cost, schedule, and quality of the project. The student teams are primarily graded on their team's ability to manage the project cost and complete the project on schedule to the identified quality standards. This focus adds ample complexity to the project since teams are required to complete most of the management work during the 3-hour lab period.

The Last Planner® System in the Construction Project Controls Lab

The Last Planner® System is incorporated into all phases of the lab to simulate use of the system on a 'real' project. At this point, it should be reiterated that LPS is a ***production control system***. Thus the primary effort of implementing LPS in this lab occurs during the construction phase. Regardless, student teams are required to complete all elements of LPS throughout the lab.

Element 1 - Master Scheduling: Student teams create a milestone schedule during the first week of the pre-construction phase. The milestone schedule is typically a simple bar chart schedule created in Microsoft Excel. However, student teams are allowed to use any scheduling platform to meet this requirement. The primary goal is to identify the major milestones of the project, such as "foundation completion", "framing completion", "dry in", etc. Additionally, teams should identify any 'long lead' items that require a longer period to procure.

Element 2 - Phase "Pull Planning": In the second week of the pre-construction phase, student teams conduct a 'phase pull planning' session. Students each research a specific scope of work and thus become the 'last planner' for that scope during the pull planning activity. Students are reminded to focus on discussing 'hand offs' between each scope of work. A pull plan is completed using 'Post It® notes' as traditionally done on lean construction projects.

Element 3 - Make Work Ready Planning: The final week of the pre-construction phase requires student teams to create a three-week LAP. This allows the teams to identify the constraints to upcoming activities and to 'make the work ready' for the upcoming weeks. This becomes a key learning opportunity for students to understand how to identify and address constraints.

Element 4 - Weekly Work Planning: Each week the teams are required to conduct a Weekly Work Plan meeting at the completion of the lab period. Students review this week's WWP and create a detailed work plan for the next week. The WWP is using a Google spreadsheet template provided by the instructor.

Element 5 – Learning: Students are continually reminded that the learning portion of the Weekly Work Plan meeting is at the 'heart' of lean construction and LPS. Thus the instructor continually reviews the Percent Planned Complete chart and Variance Log with student teams. These tools provide a consistent way for teams to improve performance each week.

Reflections on Implementation

The CPC lab began in the Fall 2013 semester. The instructor decided to make LPS a cornerstone of the management system in the lab since students were introduced to it during the preceding construction scheduling course (Hyatt, 2011). Each semester provided interesting results for the consistent implementation LPS process.

Semester 1 - Just Do It: During the first semester, student teams were primarily focused on completing the project as quickly as possible and thus quickly lost focus on the most important aspect of the lab … ***managing the work***. The instructor added a mandatory required to complete the Weekly Work Plan meeting in order to address this issue. This meeting forced the student teams to slow down and review the key production management aspects of the project. The student teams did complete the required meetings, but the documentation for each meeting was not consistent across the teams. Thus, the key benefits of LPS (collaborative planning and continuous learning) were not fully identified by the teams.

Semester 2 - Online LPS Documentation: In order to address inconsistent LPS documentation, the instructor created standard templates for all elements of the system. This created better standardization for teams to utilize during the WWP meetings. The forms were created and shared in Google Drive so as to allow easy access to students. The result was a more consistent use of LPS on the project, but many of teams failed to use all of the documents on a weekly basis. Some teams would update the documents, but not use them during their WWP meetings. Other teams would refer to the documents, but not fully complete them each week. Ultimately it was an improvement from the first semester, but the online documents did not fully address the issue of consistency.

Semester 3 - Visual Control Boards: The most recent adjustment was to print hard copies of all documents and post them on a 'visual control board' for each team. These boards were located adjacent to the lab site and to be easily reviewed by the teams at any time. It also provided an ideal tool for student teams to use on a consistent basis when conducting their WWP meetings. Finally, the boards were consistently updated since every team member was accountable in a visible way. This method of documentation was the most successful implementation of LPS.

Student Feedback

The instructor solicited feedback from students during the course of the lab in the most recent semester. Feedback was collected using an online survey, which was optional for students. Most of the students (16 of 20) completed the survey. Here are some of the students' comments:

Question: What do you like about the Last Planner® System in the lab?

- I liked that it is explained well in each class and repeated and therefore it can be applied easily.
- That it gives us a great idea on what we planned and we can compare what we have completed to what was originally intended to be completed.
- I think is a pretty effective method to complete work on time. By recording on paper when we plan to complete specific activities forces us to stay focus(ed) and achieve 100% completion on such activities.

Question: What do you not like about the Last Planner® System in the lab?

- It can be complicated at first.
- I do not like that plans change and we sometimes cannot do activities that were planned.
- I don't think we are using it to its full capabilities.
- Sometimes you can't get activities done that you had planned because of unexpected things happening.

Discussion

Consistent use of LPS in the lab periods proved to be challenging the first couple of semesters. This was surprising since all of the students were introduced to the theory and practices of lean construction and LPS in the prerequisite course. Even more surprising was the acknowledgement that LPS was an effective tool to ensure successful completion of the project in the given time frame.

The addition of a 'visual control board' with hard copies of all documents greatly improved use of LPS on by the lab teams. Some of the student comments demonstrate the impact of using the visual control system to effectively manage the work. Additionally, some of the comments about what students 'did not like' summarized the key learning aspect of LPS … that they could identify the reason(s) for failures and try to address them in future weeks.

The author reflected upon and analyzed the potential causes of the inconsistent use of LPS in the labs and identified the following reasons:

- The lab 'build' is relatively new to students and challenges them to use 'hands on' skills of which they may not be familiar. For example, so students have never participated in wood framing activities prior to this lab. Therefore, they focused more on the construction work itself and less on the management activities.
- The lab is new to the academic program and to the instructor. Actual construction adds significant logistical issues (i.e., safety, materials management, etc.) throughout the semester that causes the instructor to focus more on logistical issues than on 'mentoring' students in the use of LPS.
- Finally, teaching LPS (in the scheduling course) and apply LPS in a lab environment are two different things. Especially when the instructor has limited experience with LPS on a real project. The experience of applying LPS in the lab greatly enhanced the instructor's ability to mentor the lab teams with LPS use.

Lessons Learned

Implementing the Last Planner® System into this construction education lab proved to be challenging. However, the instructor was committed to continually improving application of LPS in the lab each semester. This process of continuous improvement provided several key lessons learned for future implementation.

These lessons learned included:

- To mentor teams using LPS (or any management system), you must first apply it on a project;
- Visit as many industry projects using LPS to see how it's 'really done' in the field;
- Provide clear instructions on how LPS is utilized in the specific lab setting;
- Use a 'visual control board' with hardcopies of all documents to encourage consistent use and accountability;
- Demonstrate the key benefits (collaborative planning and continuous learning) implementing LPS on a daily basis.

Next Steps

The implementation of LPS in the CPC lab has been highly rewarding. Anecdotally, several alumni have mentioned how this class introduced them to LPS, which they now use on their projects. Additionally, the author has personally expanded his knowledge of LPS and lean construction core concepts and tools. Building upon this expansion of knowledge, the author plans the following upgrades/changes for the coming semesters:

- Expand the time spent on the lab activities from 3 hours per week, to 4 hours per week. This will be accomplished by using of the weekly lecture hours for lab 'production planning and management'.
- Revise the prerequisite course (scheduling) to focus more the knowledge and skills required for 'production planning and management'.

Conclusion

Lean construction is a growing trend in the industry. The promise of lean construction is to deliver projects quicker, cheaper, and with better quality. This paper demonstrates how lean construction practices, specifically the Last Planner® System, can be implemented into a construction education lab. The experiential learning aspect of the lab provides a unique opportunity for students to lean both the core practices and the intricacies of using LPS on a project. It is the author's opinion that LPS can be easily implemented into a construction management type lab because of the systems simplicity. Construction educators should find innovative ways to integrate lean construction and production design into their curricula. The approach described in this paper is one way to accomplish this goal.

Special Notes

The following links to documents for the Fresno State Construction Project Controls Lab are provided for your reference. Feel free to review and use these documents at your discretion. Any comments and/or questions can be forwarded to the author.

Construction Project Controls Lab Documents:

- Construction Project Controls (CPC) Lab Manual: http://goo.gl/juIS50
- Last Planner® System (LPS) Instructions for CPC Lab: http://goo.gl/8jPYVl
- LPS for CPC Lab Forms: http://goo.gl/FkuAFa

References

Ballard, G. (2000). "*The Last Planner System of Production Control*". Ph.D. Thesis. Faculty of Engineering. School of Civil Engineering. The University of Birmingham.

Forbes, L., Ahmed, S. M., Yaris, C. E., & Batie, D. L. (2014). Incorporating Lean in CM Education to Improve the Construction Industry-Proposing a Model, *Proceedings of the Associated Schools of Construction 50th International Annual Conference, Washington, D.C., 26-28 March 2014*.

Howell, G., Ballard, G., and Tommelein, I. (2011). Construction Engineering – Reinvigorating the Discipline. *Journal of Construction Engineering and Management*, 137(10) 740-744.

Hyatt, B. (2011). A Case Study in Integrating Lean, Green, BIM into an Undergraduate Construction Management Scheduling Course, *Proceedings of the Associated Schools of Construction 47th International Annual Conference, Omaha, Nebraska, 6-9 April 2011*.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. New Jersey: Prentice-Hall.

Korman, T. (2013). Design and Implementation of an Experiential Learning Exercise for a Commercial Building Construction Management Course, *Proceedings of the Associated Schools of Construction 49th International Annual Conference, San Luis Obispo, CA, 10-13 April 2013.*

Lean Construction Institute. (2014). *The Last Planner*®. Retrieved September 28, 2014 from http://www.leanconstruction.org/training/the-last-planner/

Liker, J. K. (2004). *The Toyota Way*. New York: McGraw-Hill.

McGraw Hill. (2013) *Smart Market Report*, McGraw Hill Construction, New York.

Smith, A. (2011, September 22). Agile and Lean Applied to Construction Message posted to http://ennova.com.au/blog/2011/09/agile-lean-compared-applied-construction

Tingerthal, J.S. (2013). C4P Construct for Practice - The Integrated Construction Laboratory, *Proceedings of the Associated Schools of Construction 49th International Annual Conference, San Luis Obispo, CA, 10-13 April 2013.*

Tsao, C. C., Azambuja, M., Hamzeh, F. R., Menches, C., & Rybkowski, Z. K. (2013). Teaching Lean Construction - Perspectives on Theory and Practice, *Proceedings of 21st International Group on Lean Construction Conference, Fortaleza, Brazil, 2013*.