# Action to Improve the Reliability of Production Planning

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**Abstract**

Management of today's dynamic projects requires a shift of focus from product to process. The purpose of traditional project controls is to conform performance to plan. The purpose of lean project controls is to make the best possible choices at each point in time during the course of the project, as well as contributing knowledge to the parent organizations so they can learn from project experience.

The Lean Construction Institute(LCI) proposed the Last Planner System(LPS) capable of accomplishing that purpose, principally through controlling the quality of planning and of management processes themselves, as distinct from concentrating exclusively on project performance.

The case project was a pilot project for the implementation of the Last Planner. Consequently, the coordination of the work on this project was extremely successful. The project had its share of challenges. The coordination did not prevent design problems, or supplier errors, but helped the team deal with the problems effectively while maintaining the work flow. The last planner helped the contractors know: a) who will be doing what and where, b) what each one needs from the others, and c) what are the project priorities. The system itself created a more collaborative environment, because it "demands" that the subcontractors address these issues.

## 1. Introduction

The definition of control in traditional construction is monitoring against schedule and budget projections, while lean construction defines control as causing events to conform to plan.

A well structured production planning system does not rely for control only on feedback from its own production processes, but also collects control information from its supplier processes in an attempt to understand and thus shape the flow of work coming toward it. In a well-structured system, suppliers provide not only resources to customer processes, but also information for planning.

Management processes, not only project outcomes have to be controlled. Traditional outcome measures such as cost and schedule can only be used for management decision making on dynamic projects when the project management systems are themselves in control. The primary indicator of such control is the reliability of production planning.

Consequently, the purpose of traditional project controls is to conform performance to plan. The purpose of lean project controls is to make the best possible choices at each point in time during the course of the project, as well as contributing knowledge to the parent organizations so they can learn from project experience.

The Lean Construction Institute(LCI) proposed the Last Planner System (LPS) capable of accomplishing that purpose, principally through controlling the quality of planning and of management processes themselves, as distinct from concentrating exclusively on project performance.

In this paper, a case study was carried out to assess lean construction. The assessment of how properly LPS is implemented in real construction sites and the evaluation of its' effectiveness was examined as well. This project was a pilot project for the implementation of the Last Planner. The goal was to test if the implementation of the Last Planner method improved the control of production and the performance of the project.

## 2. Literature Review

### 2.1 Work Flow

Management of today' s dynamic projects requires a shift of focus from product (output) to process (input). This shift has two parts: 1) from production outcomes to production processes, 2) from production to management processes.

A key element in this process-oriented approach is the management of workflow. In manufacturing, the flow of work is determined by the layout of factory. However, in construction, workflow is administratively controlled

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through production planning. "Work" in the term "work flow" refers to the elements of assignments; i.e. what makes an assignment workable, and so includes primarily drawings and specifications, other information, materials, and prerequisite work. These are the streams usually outside the control of those responsible for executing assignments. Within their control are work elements such as tools and equipment, permit, accessibility, and labor. Matching labor and its instruments with 'external' work flows is a key to cost and schedule performance for all production centers, whether they are producing drawings, purchase orders, fabricated pipe spools or completed foundations.

Workflow predictability partially determines:

- adjustment of interdependent flows
- match of labor with available work, both in type and amount
- assembly of production resources
- detailed crew level planning

2.1.1 Stabilization of Work Flow

According to the lean construction glossary defined by the LCI, "the work flow is the movement of information and materials through a network of production units, each of which processes them before releasing to those downstream." Under lean construction, stabilizing workflow and improving its reliability is an important and required task to get successful achievement of the LPDS.

For the stabilization of workflow, backlog [1], shielding [2] and transparency are required. The backlog makes it possible to match labor and labor-related resources such as tools, equipment and temporary facilities. Shielding occurs at the level of the Last Planner commitment. The benefits of shielding are that expectations can be met. At the foremen and crew level confusion and ambiguity decrease, and non productive time falls such as waiting, hunting for something to do, rework and moving to alternative work without completing the planned work in that week. Lean construction emphasizes decentralization, and it means that low level management can have the authority to make a decision for its own work. To give authority to low level management, transparency is required. Transparency can be obtained by reducing the interdependence between productive units, using visual devices, making the process directly observable, incorporating information, and keeping a clean and orderly workplace.

The stabilization of workflow can fail when direct workers inherit uncertainty and variation of workflow and there is non-productive time and de-motivated workforces. Most problems usually occur in the quality of planning. To prevent these problems, there are three solutions: educate the planner, improve planning, and clarify and modify directions (orders). Obstacles that prevent the stabilization of work flow are identified as follows: lack of information, lack of materials, low workforce utilization, poor planning, no on-time deliveries, no matching of labor to resource, and rework.

2.1.2 Reliability of Work Flow

Improving workflow reliability is important for the productivity of linked production units, and consequently for project cost and duration (Ballard, 1999). One measure of workflow reliability is Percent Plan Complete (PPC). Four actions are recommended to improve PPC and work flow reliability. The first is full empowerment of the last planners to refuse assignments that do not conform to quality criteria. The second is further improvement in definition by using "First Run Studies in construction and Activity Definition Models in design" (Ballard, 1999). The third is a consistent analysis and action on reasons for failing to complete assignments, and the fourth is adopting a sizing criterion for assignments that consistently demands less output from production units than their estimated average capacity in order to accommodate variability.

2.2 Traditional and Lean Controls

The following table 1 presents compares traditional practice with lean

Table 1. Comparison of Traditional and Lean Controls (Howell and Ballard 1996)

| | Traditional | Lean |
|---|---|---|
| Purpose | To conform performance to plan | To adjust ends and means |
| Project Objectives | Fixed in magnitude and relationship between dimensions | Changing |
| Standards | Arbitrary reflections of market circumstances | Unprecedented performance targets adjusted based on field studies |
| Significance of Variation | All variances are significant and signify execution failure | Variation is statistically analyzed. Significant variances may result from plan quality(management) failures or execution failures |
| Performance Dimensions | Safety, Quality, Budget, Duration monitored separately | What is the cost and time required achieving quality? |
| Focus of Control | Subprojects and people | Work Flow and Plan Quality |
| Forecasting | Assumes future will be an extension of the past | Forecasts basted on documented variation and workflow |
| Performance Assessment | Assess performance against SHOULD, disregarding CAN | Assess performance against SHOULD within the limits of CAN |
| Measurement Accuracy | Misreporting of performance against objectives is a result of evil intent and is to be countered with harsher penalties and 3rd party snoops | Misreporting is rational, a consequence of system design, and will continue until the management system is changed |

construction approach to controls.

## 3. Case Study

### 3.1 Project Description

The project scope included a 15,000 square foot process chemistry lab and office space tenant improvements within the second floor of an existing building shell, and approximately 2,000 square feet new exterior electrical/mechanical space for a 1000 kilowatt generator, cooling towers, chillers, pumps, and associated equipment. The project also included an extensive upgrade of HVAC and electrical systems (including redundancy and capacity for future build out). The project was located in California. The project contract was approximately $5.5 million and the project duration was six months. The project was almost completed at the time contact was made.

### 3.2 Results

Results were gathered from interviews with subcontractors, and collection and analysis of the short questionnaire survey.

#### 3.2.1 Project Planning Systems and Process

The project employed a six-week lookahead, Weekly Work Plan, and PPC. The Last Planner process involved the following steps on a weekly basis:

- Monday: Collect information from foremen about the constraints of their upcoming activities and update the project schedule (GC team)
- Tuesday: Coordination meeting
  1. Review the previous week's activities - what was completed, what was not completed, PPC
  2. Discuss reasons for incomplete activities
  3. Review six-week lookahead and constraints, identify what is "ready"
  4. Develop Weekly Work Plan for the following week
- Tuesday (but sometimes later): Distribute the WWP to foremen.
- Thursday: Distribute the six-week lookahead to subcontractors, so they can prepare for next Tuesday's meeting

#### 3.2.2 Observations

There were early difficulties in establishing the "system." The project team was very dedicated to the implementation despite early difficulties, and developed a very good system that was easy to use and up-to-date (once it was set).

Coordination meetings were held to one hour in length. The team improved the Planning Reliability. The PPC in Figure 1 was consistently around 80% the last few weeks. As the increased PPC shows, the project team got better in executing what they planned to do. In the action of planning and scheduling, the system forced the general contractor to plan in great detail and to be extremely disciplined with keeping and updating the six-week schedule. Subcontractors provided input regarding their work needs which forced some of them to better identify their needs.

The project had better coordination among subcontractors regarding pre-requisite work constraints (the detailed work sequence), and developed a good environment for cooperation. The team systematically identified and

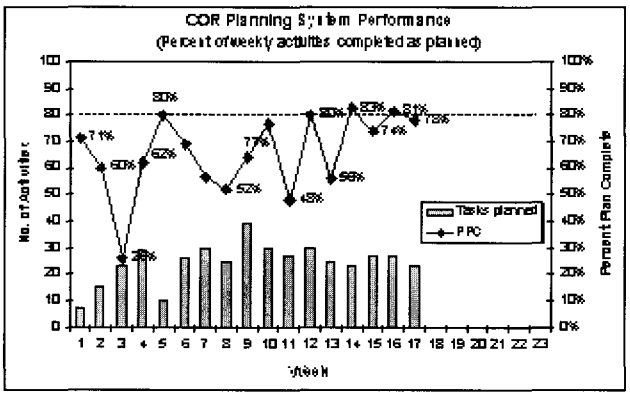


Figure 1. Percent Plan Complete (PPC)

removed constraints that could delay work. There was much better communication of the weekly plan with responsibilities to all. The team reduced the "disconnect" between the general contractor's plan and the subcontractors' work.

For most subcontractors, their lookahead planning was not detailed enough. However, the constraint analysis was improved. Subcontractors often did not come prepared. They did not have much of the information they needed such as delivery time for critical material and equipment. Problems with information were often discovered after work had been started.

There was difficulty in securing 'Reliable Promises' from the subcontractors in the coordination meeting. Some tasks stayed in the plan as "optimistic goals to shoot for" rather than positive "will do".

The project also had difficulty in determining exactly what work would be accomplished the following week. The project did not have a specific WWP every week. Part of the problem stemmed from not having all the "right" people present at all the meetings.

Subcontractors' commitments and declaration of completeness were needed. The project had limited root cause analysis of reasons for incomplete activities.

### 3.3 Feedback from Interviews

The key contractors' foremen and project manager were interviewed, and the interviewees included the mechanical sheet metal foreman, mechanical piping foreman, mechanical startup foreman, electrical foreman, plumbing

foreman, and the mechanical project manager.

Interviews were conducted focusing on the following four questions and analyzed the results based on each question. All questions were on a 1 to 5 scale. One (1) represented 'much worse' or 'much less', and five (5) represented 'much better' or 'much more'. Three (3) represented the average.

- Planning & Coordination: Compared to other similar projects not employing lean construction, how was the planning and coordination on this project?
- Fire-fighting: Compared to other similar projects not employing lean construction, how many unexpected and urgent problems have been experienced on this lean project?
- Productivity: Compared to other similar projects not employing lean construction, how was the productivity on this project?
- Unplanned Overtime (OT): Compared to other similar projects not employing lean construction, how was the unplanned OT on this project?

The summary of responses in Table 2 showed that the Last Planner System increased planning and coordination in the project and less unplanned overtime and unexpected urgent problems were experienced. No productivity improvement was discovered in this project.

The following shows the details from interviews with subcontractors, based on each question. Respondents described the benefits of lean construction and gave comments on opportunities for improvement.

Table 2. Summary of Responses from the Subcontractors

| Question | Mech. Sh-Mtl | Mech.Piping | Mech-Start Up | Electr. | Plumb | Mech. PM | AVG |
|---|---|---|---|---|---|---|---|
| Planning & Coordination* | 4 | 4.5 | 5 | 3.75 | 4 | 5 | 4.4 |
| Fire-fighting | 2 | 2 | 2 | 4 | 1 | 4 | 2.5 |
| Unplanned OT | 2 | 1 | 1 | 2.5 | 1 | 2 | 1.6 |
| Productivity* | 4 | 2 | 3 | 4 | 5 | 2 | 3.3 |

(*) indicates 'High score is better'.

### 3.3.1 Planning and Coordination: high score indicates 'improvement'

| Contractor | Score | Benefits | Comments |
|---|---|---|---|
| Mechanical-Sheetmetal | 4 | On this job, knew what all subs were working on.Meetings communicated needs and addressed issues for following weeks.Communicated priorities. | All players need to communicate well, limited benefits if only few do it. |
| Mechanical-Piping | 4.5 | Recognized issues-got answers faster.Good cooperation between subs. | Too much work at the end of the job, but no work was in the way |
| Mechanical-Start-up | 5 | Unique coordination meetings on this job. Very well organized, very useful. Helped work well with other subs. | |
| Electrical | 3.75 | Knowing what everyone will be doing was useful. More in-depth coordination and preparation. The "board-to-board" system was best. | Some scope not communicated well. |
| Plumbing | 4 | Coordination better than any other contractor. | Only problem early on, when working on wrong priority. |
| Mechanical PM | 5 | Challenging project, a lot of work in small space. Great planning and coordination. Got the plan on the table, addressed the issues. The flow was great. | Unforeseen issues with existing systems |

### 3.3.2 Fire Fighting: low score indicates 'improvement'

| Contractor | Score | Comments |
|---|---|---|
| Mechanical-Sheetmetal | 2 | Minor issues (not fires). |
| Mechanical-Piping | 2 | Some coordination problems mainly with own shop. |
| Mechanical-Start-up | 2 | Keeping existing equipment on line with minimum downtime (occupied facility). Some coordination issues with own subs |
| Electrical | 4 | Scheduling work with PG&E was a problem.Last minute scope from mechanical design. Near the end many things came up that were not in the plans. |
| Plumbing | 1 | No urgent issues. |
| Mechanical PM | 4* | No fire-fighting from field coordination. Mostly issues with own start-up subs. Difficult to get realistic commitments and manpower. The fume hood problem was important "fire," but it was well coordinated and maintained the flow. |

(*) It is interesting that the mechanical project manager felt more "pressure" than the three mechanical foremen. Two probable reasons could

account for this: first, he was less experienced with this type of project; second, he was under pressure to meet the field's requirements, and had many different constraints to address from suppliers, design (the mechanical part was design-build), design coordination, and start up subcontractors.

3.3.3 Unplanned Overtime (OT): low score indicates 'improvement'

In addition to asking the foremen, the general contractor also checked the company's log for change requests that subcontractors submitted for over time.

| Contractor | Score | Comments |
|---|---|---|
| Mechanical-Sheetmetal | 2 | No unplanned OT. Reasonable schedule, worked smoothly |
| Mechanical-Piping | 1 | Normal weekend shutoffs-No unplanned OT |
| Mechanical-Start-up | 1 | No unplanned OT |
| Electrical | 2.5 | 1– About 110 hrs OT of approx. 4,000 total hrs < 3%<br>2- Fume hood wires not connected from shop-added RCE scope: 80 hrs OT<br>3- Lights: 30 hrs OT to release area. |
| Plumbing | 1 | No unplanned OT-only planned shut-downs |
| Mechanical PM | 2 | More than 3,000 hrs total. OT about 10%, 300hrs. OT due to occupied facility. Minimal OT due to emergencies or coordination problems. |

3.3.4 Productivity: high score indicates 'improvement'.

| Contractor | Score | Benefits | Hours |
|---|---|---|---|
| Mechanical-Sheetmetal | 4 | Had areas ready to go. Good coordination. Checking "ready" work was good | Approx.: 4 x 10 wk = 40wk x 40=1,600 hrs |
| | | practice, very little "jumping around." | |
| Mechanical-Piping | 2 | Some rework due to internal problems (*) No impact from other subs. DPR | Approx. 1,000 hrs (800 since September) |
| | | and subs very helpful on this job. | |
| Mechanical-Start-up | 3 | Some impact from Electrical design (lighting panel, low voltage) | Approx. 400 hrs |
| Electrical | 4 | Some impact from in-house coordination with design, and PG&E.On this | About 4,000 hrs |
| | | job, very small impact from other subs. Did not have to jump around. | |
| Plumbing | 5 | On this job, all knew what others were doing and where others were going to be. | Hours: 4 avg. x 15wk =60 x 40 = 2,400 |
| Mechanical PM | 2 | Given the complexity of the project, it was ok, but exceeded hours. Some | Approx. hrs (sm=1,300, pp=1,500, su=400) |
| | | problems with our own piping design created problems in the field. Some | |
| | | more hours for startup. | |

(*) It should be noted that the mechanical piping foreman who started the project was replaced halfway through the job due to lack of performance and difficulty in coordinating and working with other foremen (including the other mechanical crews-startup and sheet metal).

## 4. Conclusions and Comments

The researcher conducted interviews with the general contractor and subcontractors focusing on the benefits and opportunity for improvement of using the Last Planner, and then, proposed some actions to prevent difficulties in lean implementation in the future. To prevent early difficulties in establishing the day-to-day implementation details and forms, the researcher suggested spending 20% of time on lean theory and 80% on "how-to" during the introduction of Last Planner. For the lack of detail for some project activities, the researcher recommended to make an activity "breakdown" using the pull schedule.

The subcontractors' lookahead was not detailed enough because foremen did not have all information they needed and did not get enough prompting from the general contractor. Project problems occurred with activities where the subcontractors' planning was weak. To improve the subcontractors' lookahead schedule, setting clear expectations and agreement in the beginning of the project, and gathering input from subcontractors' project managers and suppliers should be absolutely required. The project manager and superintendent consistently required the weekly lookahead reviews with the subcontractors, and they helped subcontractors' foremen with lookahead schedule. The general contractor kept emphasizing the importance of high

PPC (reliability), and identifying the reasons for incomplete work.

According to the subcontractors, the coordination of the work on this project was extremely successful. The project had its share of challenges. The coordination did not prevent design problems, or supplier errors, but helped the team deal with the problems effectively while maintaining the workflow.

Despite the project conditions (a lot of work by several contractors in a small area) and the unforeseen problems (mainly fume hoods, scheduling PG&E, and some electrical requirements that were introduced late), the work was well coordinated, and the workflow was maintained. No productivity problems occurred due to workflow and coordination.

According to the subcontractors, this type of project usually has a lot of coordination problems. On this job, the subcontractors did not identify any significant coordination problems. Some productivity issues were caused either by incomplete design, supplier problems, or manpower allocation. The coordination method made everyone a better "team player."

The last planner helped the contractors know: a) who will be doing what and where, b) what each one needs from the others, and c) what are the project priorities. The system itself created a more collaborative environment, because it "demands" that the subcontractors address these issues.

Opportunity for improvement includes the need for more in-depth review of the design constraints in the six-week lookahead schedule. This can improve design management and align the design with field needs.

According to the data observed by the project participants, this project had well-organized lean planning systems and properly implemented them enough to obtain successful results. Effects of weekly lean planning meetings were investigated as well.

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