PRODUCTION CONTROL PRINCIPLES

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ABSTRACT

This paper reports the results of a search for the principles of production control. The search starts from the Last Planner[4] system, develops its principles, functions and methods, then explores their applicability to designing and making, the primary types of work involved in project production systems.

What differences in these types of work make a difference for control? What adaptations of principles, functions or methods and tools are needed for different types of work?

The authors tentatively propose that the principles and functions derived from Last Planner are applicable to the types of work involved in project production systems, and that methods now in use can be successfully adapted for those types of work. The paper concludes with a description of needed research.

KEY WORDS

Last planner, principles of production control, production control, types of work

INTRODUCTION

The Last Planner system of production control is in wide use throughout the world. Despite successful applications in both design and construction phases of projects[5], there is a lingering question: Do we need something somehow different in design?

The authors take the position that a framework is needed for exploration of this question; a framework built around principles, functions and methods of production control. Methods used in the construction phase of projects may not be appropriate for design work, but the principles and/or functions may remain the same. Some methods may be applicable to all types of work, while some may require adaptation, and some may be peculiar to different types of work.

Our concern is not to defend Last Planner, but rather to provide a framework for productive inquiry. Is there a set of production control principles that are equally applicable to both designing and making? Are there functions and methods of production control equally applicable? If adaptation is required, what differences in types of work drive that adaptation, and at what level: methods, functions, or

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[4] Last Planner is trademarked by the Lean Construction Institute. As a courtesy to readers, the trademark symbol has been omitted from this text.

[5] Koskela, et al., 1997; Ballard and Koskela, 1998; Ballard, 1999, 2000a, 2000b, 2002; Choo, et al., 2004; Hammond, 2007; Nickerson, 2008.

principles? We start from Last Planner because it is currently the production control system in widest use in construction project management, relying on earlier arguments to the effect that traditional project controls are not production control systems at all (Ballard & Howell, 1998).

Our objective is not to settle a question, but to reframe an issue to enable research and progressive learning. Otherwise, there is a risk that champions of different approaches will settle for advocating 'brands' rather than developing theory and practice. Production control in design is an important issue. To move forward on this issue as a community of learners, we need a better framework than has previously been proposed. We hope to provide that framework in this paper.

In the sections that follow, we first describe the principles, functions and methods of production control that are currently associated with use of Last Planner. We then turn to the issue of types of work and what differences make a difference for production control. Two case studies are presented that illustrate successful application of the proposed principles of production control to designing, conclusions are drawn and recommendations for future research are proposed.

LAST PLANNER

The Last Planner system of production control can be characterized in terms of the principles that guide thinking and action, the functions it enables to be performed, and the methods or tools used to apply those principles and perform those functions. These have not previously been published, but are arguably implicit in earlier publications.

PRINCIPLES

- Plan in greater detail as you get closer to doing the work[6].
- Produce plans collaboratively with those who will do the work.
- Reveal and remove constraints on planned tasks as a team.
- Make and secure reliable promises.
- Learn from breakdowns.

FUNCTIONS

- Collaborative planning
- Making Ready
    - Constraints identification and removal
    - Task breakdown
    - Operations design

[6] This first Last Planner principle should not be interpreted to prohibit producing a detailed master schedule at the beginning of a project. How else would one explore risks and alternative strategies and hence make a prudent decision if to pursue schedule milestones? Indeed, in the 2nd case study below, the project team collaboratively produced a detailed master schedule. However, such a detailed master schedule will be wrong in exactly the way forecasts miss the mark the further into the future they extend, and the greater the level of detail they presume. The sense of the principle is, regardless of the level of detailed schedule previously produced, rethink the work plan and schedule, phase by phase, with those who will actually perform the work of each phase.

- Releasing
- Committing
- Learning

METHODS AND TOOLS

- Reverse phase scheduling (aka 'pull planning', 'pull scheduling', 'phase scheduling', stickies-on-a-wall)
- Constraints analysis; constraint logs; risk registers
- Task hierarchy: phase/process/operation/steps
- First run studies
- Daily huddles[7]
- Reliable promising
- Metrics
    - Percent plan complete
    - Tasks made ready
    - Tasks anticipated
- 5 Whys analysis

The principles are based on a number of different theories, including the theory of decision making under uncertainty (March, 1994) and the theory of speech acts (Searle, 1969), which is the basis for Fernando Flores' work[8]. (Determining the theoretical foundations of Last Planner is an area of needed research that is only mentioned here).

Though originating in attempts to control production in construction projects, the functions align closely with the theory and practice of production control in manufacturing and in product development, especially with Toyota's Production System and Product Development System.

The methods and tools are naturally the most dynamic, as practice and experimentation reveal better ways of performing functions. Another factor is the increasing maturity and competence with production control on the part of industry practitioners, who become ready for more difficult and rewarding challenges; e.g., planning construction tasks to the day rather than the week, as was advocated in the earliest versions of Last Planner.

TYPES OF WORK

We proposed above that construction projects involve two kinds of work: designing and making[9]. Making is primarily, though not exclusively, the processing of materials into products.[10] Designing covers a broad range, from conceptual design to the

[7] Daily huddles were listed as one of the then-current innovations in Last Planner practice in Ballard & Howell's "Last Planner Update" (2003), and is now in widespread use, in both design and construction, though not universally practiced.

[8] Flores, 1982; Winograd & Flores, 1987; Spinosa, Flores & Dreyfus, 1997; Solomon & Flores, 2001.

[9] It might reasonably be argued that the work in project definition—briefing, programming—constitutes a third type of work alongside designing and making.

[10] Material, information and resource flows must be designed and controlled to support product production, whether those products are essentially material or information.

production of documents. At the document production end of the range, information rather than materials are processed into products. In the experience of the authors', work flow control methods are applicable with little or no adaptation to both information and material processing. However, conceptual design work might better be understood in terms of generating, evaluating and choosing from alternative designs. Obviously, this involves information processing, but it is subordinate to what is really going on in the same way that alternately transmitting sound from ear to ear differs from having a conversation[11]. Consequently, efforts to develop design work flow control should concentrate on conceptual design, where the difference between designing and making is sharpest.

The nature of designing and its differences from making have been widely discussed. Lawson (1980) suggests that designers and science-based professionals approach problem solving in opposite ways; the latter working from problem definition to solution and the former focusing on possible solutions. His findings harmonize with the theory of wicked problems advanced by Rittel and Webber (1972). Reinertsen (1997) notes the different valence of variability, which is essential for designing but a waste in construction. Ballard (2000) advocates a conceptualization of designing as a dialectical process:

> "Rather than conceiving the project process to consist of (deriving design criteria from client requirements), then applying those criteria in the production of the design, design should be conceived as a value generating process dedicated to the progressive determination of both ends and means." (Ch. 6, page 9).

WHAT DIFFERENCES MAKE A DIFFERENCE FOR CONTROL?

What differences between types of work, especially between designing and making, make a difference for production control? Here are some possibilities:

- uncertainty of ends or means
- speed of execution
- complexity of the work

Uncertainty appears to be an inherent characteristic of conceptual design. Design options emerge from a rich stew of discussion and thought, and cannot be fully predicted beforehand. (If they could, then arguably we are not dealing with the work of designing.) This emergence obviously reduces the extent to which future task sequences can be determined. The rule to *plan in greater detail closer to the event* still applies, but the forecast period is shortened. Uncertainty of ends or means can also occur in making, with similar consequences; for example, when digging in the ground or opening up walls in an existing building.

Speed of execution affects production control by reducing the time available for preparing, for making ready. One example is the difference between a plant shutdown and a commercial building project. Because speed is of the essence in the former,

[11] Specification of conceptual design tasks may best be expressed initially in terms of alternative generation, evaluation, and selection; then progressively more detailed and concrete, describing alternatives as they emerge and take shape.

great effort is made to prearrange materials and services, the need for which will be discovered shift-by-shift. The lack of time for preparation drives up 'just-in-case' inventories. This seems to apply to both designing and making. The greater the speed of design execution, the larger the buffers incorporated in the design to allow for loads and dimensions that could not be more precisely determined in the time available. Although Last Planner principles, functions and methods still apply, methods must be adapted in response to the time available for making ready.

Work complexity is a function of the number and type of dependencies between tasks. One relevant difference between designing and making is that design tasks can be reciprocally dependent, thus rendering them more complex and necessitating a different kind of planning (e.g., use of the design structure matrix), assignment (multi-discipline teams), and execution (iteration: reciprocal dependency drives iteration in conceptual design, as the conversation between interdependent specialists must go through an indeterminate number of cycles in order to achieve alignment).

CASES

Two cases are included in this paper as examples of successfully applying production control principles, functions and methods to design. Some previously published attempts have reported difficulties engaging design professionals in work planning and control. We do not pretend to have concluded the discussion of this issue, but rather to have initiated it in a way that we hope can be more fruitful.

The first case also illustrates adaptation of methods to the work of designing. The two cases reflect quite different circumstances. The first applies production control in a design office, and one in which multiple small projects are the rule. The second applies production control in a large project, where design professionals are more often assigned exclusively for longer periods of time.

BOULDER ASSOCIATES

Tracking Commitments

Boulder Associates Architects worked for four years on Lean construction projects, before beginning an internal Lean transformation. A pilot team in the Sacramento office composed of one architect, three interns, and three interior designers began using Last Planner in March, 2008. The team met on Monday mornings to plan work for the coming week. Through the course of the week, the team leader conducted daily "huddles" at each team member's work station to monitor work and respond to questions and requests. The following Monday, the team reported their results in the team meeting, capturing planned percent complete (PPC) and variance of unfulfilled commitments. The team established a goal of 85% reliability in meeting commitments and used root-cause analysis on all instances of variance. Figure 1 demonstrates the scores of the individual team members during their first 13-week increment of Last Planner.

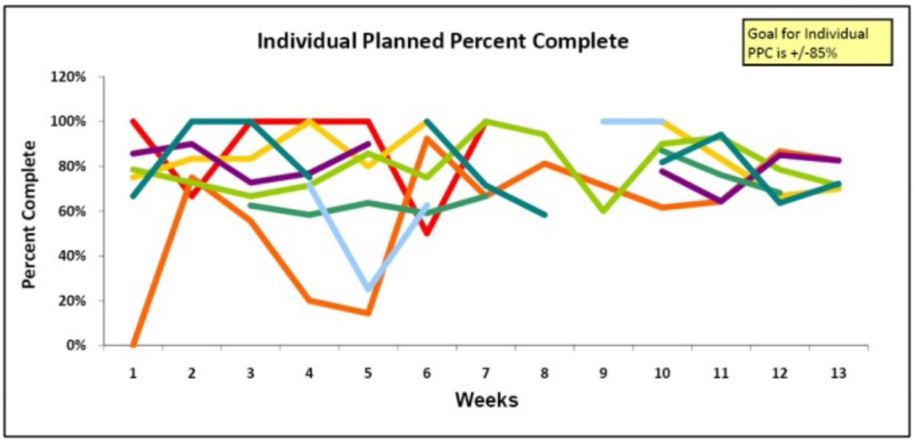

Figure 1: Scores of the Individual Team Members

The original Lean team practiced for six weeks before finding a rhythm using Last Planner. This pattern of learning repeated itself with subsequent Lean teams and may be a standard experience for new teams when first adopting Last Planner. After a few weeks of practicing, team members quickly adapt to Last Planner and normalize PPC scores. Figure 2 represents the second 13-week increment for the team and shows the leveling of PPC scores.

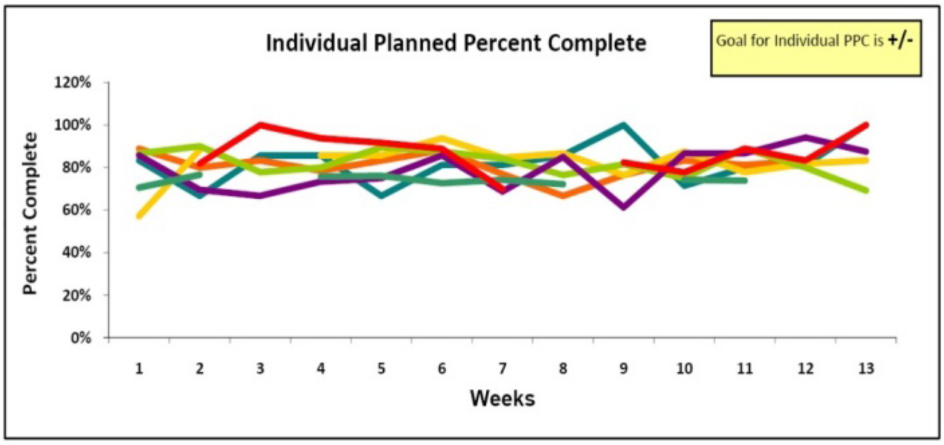

Figure 2: Increment for the Team

Boulder Associates performed an analysis of three ten-week periods in support of the Last Planner effort. Two occurred prior to the implementation of Last Planner with the third and final ten-week period coinciding with the first ten weeks of work planning. The analysis examined the total number of daily hours worked by Lean team members and revealed a dramatic reduction in overtime and off-hours work after the implementation of Last Planner. A day-to-day leveling of total hours worked by team members became apparent, despite a number of traditional overtime triggers, including city submittals and project deadlines. Last Planner helped the Lean team incorporate the work push required to meet the deadliness without adding hours. Team members also reported improvement in subjective measures including reduced stress level, an increase in perceived control over work assignments, and improved work planning ability.

Moving Beyond PPC

After firmly establishing commitment tracking, Boulder Associates implemented six-week look-ahead planning as originally described by Ballard and Howell. Look-ahead planning worked well on large projects and added value for teams working on a single project. The firm also sought a means to apply the value of look-ahead planning to the teams working on smaller projects and to individual team members. Boulder Associates created a modified form of three-week look-ahead planning customized for individuals.

The preponderance of unplanned work within a design firm significantly impacts the amount of work that can be planned with as much as half of the work in a given week coming from outside requests from clients and external team members. This leads to a constant state of "fire fighting" that undermines planned activities. Boulder Associates uses a journaling activity to illustrate this condition to team members. The team leader uses the discussion of the journal as an opportunity for root-cause analysis to emphasize the need for compartmentalizing tasks and to show the benefit of beginning, working on, and completing tasks without interruption.

NEW TOWN DEVELOPMENT – NORTH AMERICA

This case study reports how the introduction of improved methods for defining and managing work improved the overall design delivery for a new town development in North America. The $1B development comprised several major mixed-use buildings, surrounded by low density residential areas covering a total area of 500 acres.

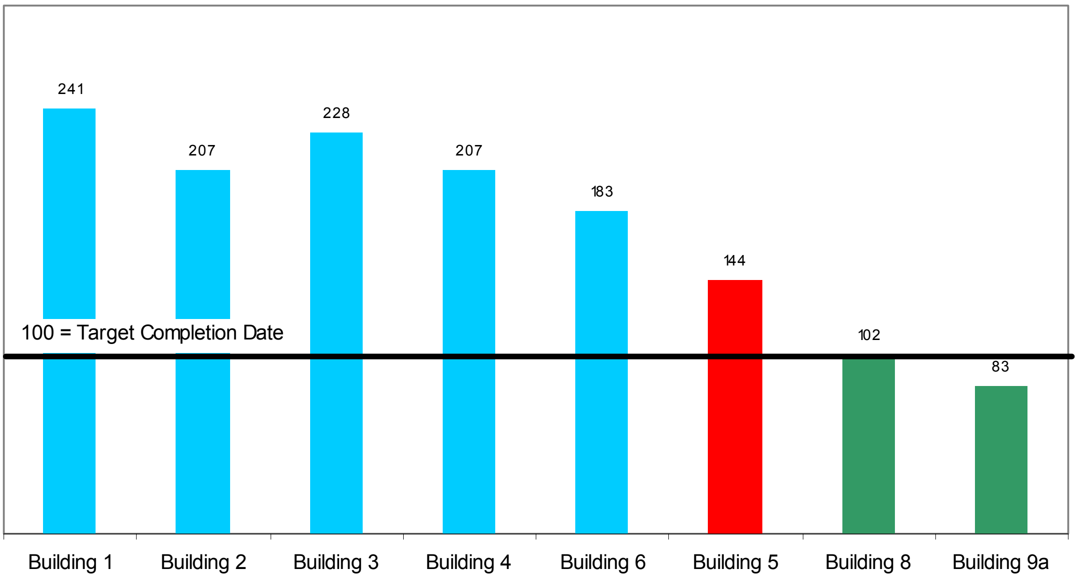

Figure 5: Actual Completion Versus Target Dates

The decision by the owner to apply the Analytical Design Planning Technique (ADePT) (Austin 1999) was based on trend data that showed that their existing methods of scheduling and managing the design process were proving ineffective. The bar chart shown in Figure 5 reports the actual completion to target date for the design of eight separate building projects in the new town, where 100 equals the target completion date as defined in the overall design schedule. Each of the eight buildings were unique by design, however, they all shared similar technical challenges, and were similar in terms of function, size and cost. Buildings 1, 2, 3, 4 and 6 were started sequentially and were completed later than scheduled. For example, the design of Building 1 was originally scheduled to take twelve months (from concept through to construction documents); however the actual duration taken was twenty-nine months.

The over-runs in design prompted the owner to reconsider the approach to scheduling and managing the design process for three further projects (Buildings 5, 8 and 9a), and the ADePT approach was used to assist the team to schedule design activity, and subsequently the Last Planner approach was implemented to support the management and control of the design process during delivery.

INTEGRATED DESIGN SCHEDULING WITHOUT LAST PLANNER

The Building 5 project was the first application of the ADePT approach. The design team spent approximately 3 days per design discipline working collaboratively to define their design tasks, information requirements, and identifying their major risks. The results were then analyzed using a Dependency Structure Matrix (DSM) analysis tool, enabling them to see their complex, interdependent relationships. The results of the DSM workshops enabled the team to make critical co-ordination decisions and agree working assumptions. Design management strategies were also derived, whether graphically (through process mapping), or in words (design working method statements/philosophies). These strategies were crucial since they unraveled problems associated with iteration in design prior to technical delivery.

The agreed and optimized design process was then imported into a scheduling tool, which enabled the team to finalize and publish a timeline for the overall delivery of the design. This represented a single integrated set of commitments, and was regarded as their Master Schedule.

The most notable result of scheduling the design activities in this way was the dramatic reduction in overall duration. When compared to the previous projects, the team had committed to delivering the design in nine months (compared to sixteen months for Building 2, which was similar to Building 5). However, the design team then went on to manage the delivery of the design without using the Last Planner technique, instead relying on more traditional forms of internal management. The actual completion of the design of Building 5 was four months later than the original schedule of commitments suggested, and whilst this was an improvement on the previous five projects, the owner felt that further improvements could be gained through the adoption of an alternative production management method.

INTEGRATED DESIGN SCHEDULING WITH LAST PLANNER

The design activity of Buildings 8 and 9a was scheduled using ADePT, in exactly the same way as Building 5. However, once the integrated design schedules (master schedules) were established, the Last Planner approach was employed to support the management of the design process during the delivery stages.

In order to accommodate the change in management methodology, the design management approach to Buildings 8 and 9a had to be reconfigured. Therefore, the team agreed a six week lookahead period and a two week focus period (which constituted the workplan) and *'design team progress meetings'* were carefully structured to facilitate the Last Planner process as follows:

- Report progress for the previous focus period
- Analysis of root cause for failure to meet commitments
- Report newly identified constraints for activities in the lookahead period;
- A review of existing commitments in the lookahead
- Impact analysis of change and rescheduling design activity (utilizing DSM);
- Action planning to resolve constraints for the next focus period;
- Confirmation of commitments for the next focus period and lookahead period.

As a result of applying ADePT and Last Planner, the delivery times for both projects improved significantly when measured against the previous projects (refer to Figure 5). In fact Building 8 was delivered on time, while Building 9a was delivered four weeks ahead of schedule.

CONCLUSIONS

What can we conclude from our review of differences between designing and making and from the two case studies? The Last Planner principles, functions, and methods presented previously in this paper appear to apply to the work of designing. Adaptation of methods is required to adjust to the level of uncertainty, speed, and complexity of work, whether it be designing or making. Methods such as the design structure matrix are peculiar to conceptual design because those tasks can be reciprocally dependent, and making tasks cannot.

SUGGESTIONS FOR FUTURE RESEARCH

Future research is needed on a number of issues and questions, including those just listed:

1. Have all the relevant differences between types of work been identified?
2. Are these differences between types of work adequately understood? What are the implications of differences in uncertainty, speed and complexity?
3. Are the principles and functions presented in this paper complete and adequate for production control of both designing and making? Is it appropriate at this stage in our learning to focus research on refinement and invention of methods?
4. What are the best methods for production control…
   a. when uncertainty reduces forecast periods?
   b. when speed reduces the lead time available for making ready?
   c. when tasks are reciprocally dependent?
   d. when merge bias reduces the probability of on-time starts?

5. How to explain instances of failed implementation reported in the literature?

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