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CYCLE TIME REDUCTION IN HOME BUILDING

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ABSTRACT

Even Flow Production is an innovation in residential construction intended to increase the reliability of work flow. That objective is to be accomplished by adherence to a standard schedule for sale, design, construction, and turnover of a home. In turn, increased work flow reliability reduces cycle time, the time required to deliver a home to a customer. Reliability increases as variability is reduced, allowing a reduction of slack in activity durations and of inventory previously needed to accommodate that variability. Increased work flow reliability is also a necessary condition for taking other actions to reduce cycle time.

This paper proposes a method for reducing cycle time within the context of even flow production. The key innovation is the formation of multicraft teams responsible for specific systems and components of a house. Each team is to be helped to: 1) Overlap activities within their phase of the work, 2) reduce activity durations through time studies, and 3) reduce work-in-process through the development of multi-skilled workers.

KEYWORDS

cycle time, even flow production, multi-skilled workers, work flow reliability

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INTRODUCTION

The basic idea of Even Flow Production (EFP) is to build homes to a standard schedule, starting and completing one home per day, week, etc. once the system is up and running. Home types may vary widely in labor content, hence in the number of days required to complete specific activities. In EFP, activity durations are determined by the largest homes. For example, framing may be allowed 8 days, even though only the largest models require the full 8 days[2]. This allows trade contractors to dedicate crews to the developer, the number of those crews being equal to the number of days in the standard schedule, as shown in Table 1, which shows the system in start-up mode.

House/Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
101	A-1	A-2	A-3	B-1	B-2	C-1	C-2	C-3	C-4											
102		A-1	A-2	A-3	B-1	B-2	C-1	C-2	C-3	C-4										
103			A-1	A-2	A-3	B-1	B-2	C-1	C-2	C-3	C-4									
104				A-1	A-2	A-3	B-1	B-2	C-1	C-2	C-3	C-4								
105					A-1	A-2	A-3	B-1	B-2	C-1	C-2	C-3	C-4							
106						A-1	A-2	A-3	B-1	B-2	C-1	C-2	C-3	C-4						
107`							A-1	A-2	A-3	B-1	B-2	C-1	C-2	C-3	C-4					
108								A-1	A-2	A-3	B-1	B-2	C-1	C-2	C-3	C-4				
		Assume: 9 day build cycle; 3 trades A,B, & C, taking 3, 2, and 4 days, resp.																		
		Start and complete 8 homes in 16 days with crews equal in number																		
		to the number of days they are on site at each home; i.e., A has 3 crews,																		

Table 1: EFP template

The system produced is a type of continuous flow process, since each home has some predetermined work to be done on it each day; e.g., painting always follows millwork. No centralized control is needed unless a home falls behind schedule. To prevent that occurring, days on which weather or other 'acts of God' prevents any home progressing are counted as if all homes were impacted. If the bad weather day was June 10th, Day 93 in the standard schedule, June 11th becomes

[2] When the range is large, homebuilders assign a duration between the largest and smallest, attempting to match the typical mix of large and small homes.

Day 93. Nonworkdays can also be declared to allow makeup time, if drawing down that contingency does not risk running out of contingency later in the year.

EFP can be understood to be following the lean construction rule to first improve work flow reliability, then go for speed. The next step is cycle time reduction, the key to which is breaking the sequential processing by fragmented trade contractors that is still present in the EFP model illustrated in Table 1.

EFP IN PRODUCTION MANAGEMENT TERMS

Improving work flow reliability through better planning and control is a central tenet of the lean construction movement. The Last Planner system of production control, developed by this author with considerable help from others, has been advanced as a means for improving work flow reliability.

Work flow reliability increases through the principles and practices of the Last Planner system of production control, which includes identification and action on root causes of variability within the production system. The Lean Construction Institute (LCI) will help its industry partners implement the Last Planner system in a fashion appropriate to residential construction and will also help establish processes for identifying and acting on root causes of variability. Relevant techniques include:

- PPC measurement and analysis of plan failures
- Application of quality criteria to assignments
- Screening potential assignments for constraints and assigning make ready actions to remove those constraints
- Rapid recovery when a home falls off the even flow schedule
    - Team production of pull schedules with team agreement on use of float
    - PPC measurement & action on plan failures in recovery plans
- Action assignments for each plan failure each week
- Weekly presentations of efforts made to prevent repetition of plan failures, rotated through all team members
- 5 Why's analysis of reasons for plan failure

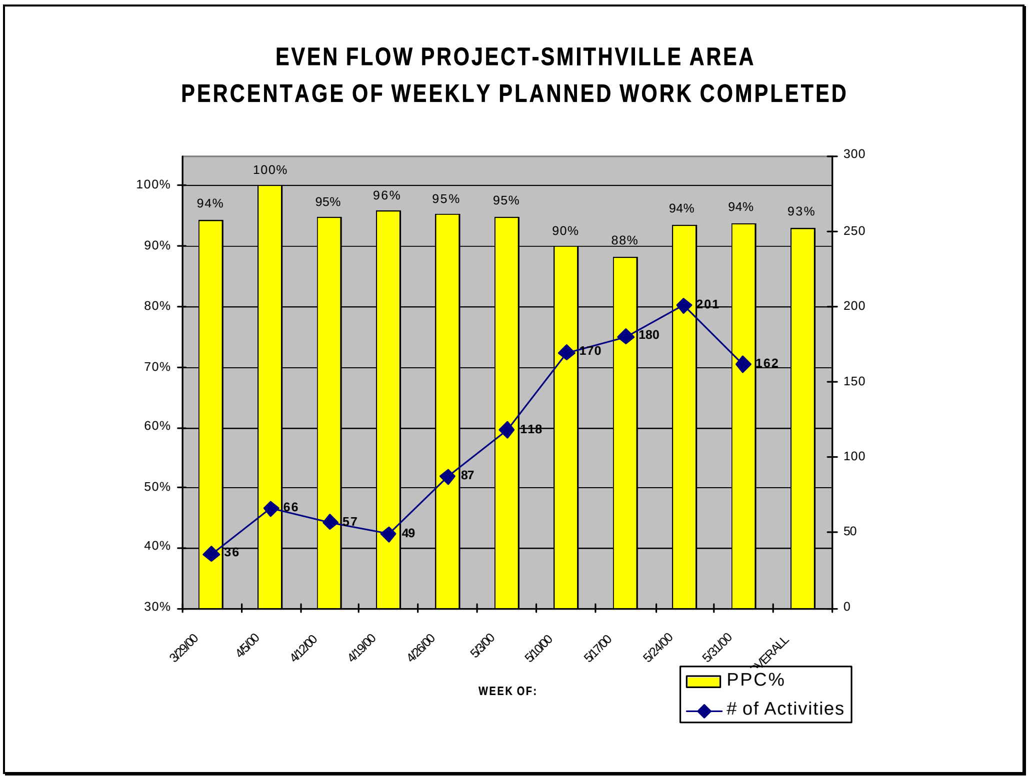

Figure 1: PPC

To the extent that trade partners based on traditional craft lines remain the organizational structure, development of the production management capabilities of those trade partners will be a vital element in the improvement of work flow reliability.

Another lean construction tenet is one piece flow. In residential construction, that would mean building one house at a time. In current approaches to EFP, there are as many incomplete homes in WIP (work-in-process) as there are days in the standard schedule template. Reducing that number of days is to be done through cycle time reduction, the time it takes to build one house. Current industry cycle time in the U.S. typically ranges from 50 to 70 working days or more. Starting one home each day in a production system with that cycle time results in 50-70 houses being in process at any one time.

To reduce cycle time, it will be necessary to break from sequential processing by fragmented trade contractors. Doing so, we propose, can yield cycle times in the 5-10 day range.

A PROCESS FOR REDUCING CYCLE TIME

The EFP/CTR research project has two foci: 1) Increasing work flow reliability and 2) Reducing cycle time. For both, the way in which the home building process is structured is vitally important.

ORGANIZING AND STRUCTURING WORK IN SYSTEM-BASED CROSS FUNCTIONAL TEAMS

A developing tenet of lean construction is to organize by cross functional teams based on the various systems that make up a facility. In the case of single family homes, teams might be formed for the build cycle[2] as follows:

- Foundation
- Structure and Skin
- Utility Rough-ins, Interior Walls, & Exterior Wall Ornamentation
- Utility & Interior Finishes
- Carpet, Driveway, and Landscaping

A very similar division was made by K. Hovnanian Companies[3] when they built their 'Fast Track Home' in less than five days. Team members should consist of everyone that can either help or harm the team's work; i.e., developer, trade contractors, craft workers, suppliers, inspectors, etc. The teams are intended to become the managers of each segment, with responsibility for planning, execution, and improvement.

Each team will be helped to reduce both work flow variability and cycle time within its segment. By moving activities between segments, the time required to build each segment can be balanced, which would largely solve the problem of including homes of different sizes within the even flow system, since work would flow from team to team on a first-in-first-out basis, analogous to assembly lines in manufacturing.[4] This would also largely solve the problem of better matching supply with demand. Initial forms of even flow production require an annual batch size of 208-220 (the number of work days actually available in a year), depending on weather impacts. Since the number of trade crews varies with the duration of their activities in the schedule template, it is very difficult to suspend production without harming the trade contractors and craft workers. With the team form of production and reduced cycle time, long term production schedules can be created that include periods of non-production should annual demand be less than 208 homes. Of course, cycle time reduction will most likely result in increased sales, so more 'assembly lines' could be created in response.

Another hypothesized benefit of this form of organization is increased productivity, and with it, increased profits for trade contractors and for craft workers being paid piecework. A possibility to be considered is to pay each team for the work of its segment, then have the team divide that pay among its members according to previously agreed levels of contribution. Obviously, this raises issues regarding the role of trade contractors, the possibility of the developer becoming the employer of craft workers, the possibility of a new form of commercial organization developing around the various segments, and so on.

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[2] Teams may also be formed for work outside the build cycle; sales, design, permitting, close out, etc.

[3] Contact Robert Hofmann, rhofmann@khov.com.

[4] See the LCI White Paper #3 "Aiming for Continuous Flow".

Benefits are also expected to come from these teams becoming self managing (see below), thus reducing the load on central coordination, and from the development of team members with skills that cut across traditional craft lines. Multi-skilled workers will help ensure timely completion of the work, will help reduce the cycle time for the segment, and is much needed in today's conditions of labor shortage.

REDUCING CYCLE TIME

Cycle time is the sum of activity durations, less overlaps between activities, plus the sum of queue times; i.e., time a part of a home spends waiting to be completed. Consequently, cycle times can be reduced by reducing queue times, overlapping activities, and reducing activity durations.

In simplest terms, queue time in residential construction is the time a home is not being worked on. It is now common industry practice for a home to stand idle well more than half the time required to build it. By overlapping construction activities, that idle time can be eliminated. The next step is to attack the queue time of the various parts of the home. For example, how long does a wall stand idle before the next work is done on it?

The recommended technique for overlapping activities is the team production of pull schedules, continuously refined based on experience and in response to changes in work methods, materials, or technology. Successful execution of these detailed plans may initially require the continuous presence of a common supervisor who can resolve conflicts and direct traffic. An LCI hypothesis is that such teams can learn to be self managing, especially if reward is team-based and contingent upon timely, safe, and quality delivery of the team's scope of work.

IMPLEMENTATION STRATEGY

The following are the steps now proposed for execution of the research in the field 'laboratory'. They may be revised in discussions with our industry partners:

1. Focus initially on the 'build cycle' portions of the entire home building cycle; from frame start through closing, which takes about half the total time now required to take a house from sale to delivery. Assuming a 60 day cycle, achieving the 16 day target from frame start would yield an overall cycle time of 46 days, a 23% reduction.
2. Divide the activities in the build cycle into 4 segments based on the various systems that make up the home and taking approximately equal time.

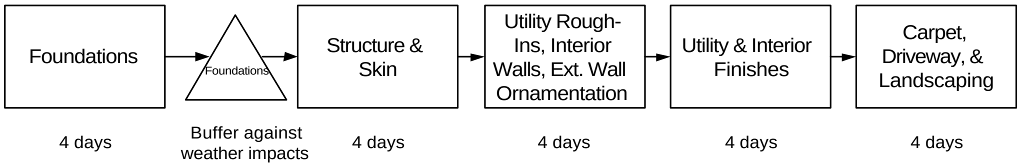

Figure 2: Interim Target Cycle Time for Build Cycle

3. Form a pilot team for a selected segment consisting of representatives of the developer, trade contractors, suppliers, craft workers, and-if possible-inspectors. We recommend starting with the Structure and Skin segment because its improvement can be buffered from upstream flows.
4. Improve EFP, PPC, and recovery plan PPC by identifying and acting on reasons for plan failure, including assignment of action items regarding each plan failure, analysis of plan failures using the 5 Why's technique, and weekly rotation of presentations explaining what a participant (developer or trade partner) has done to prevent repetition of a type of plan failure. Simultaneously, focus the pilot team on reducing the variability and cycle time of its segment.
5. In parallel with the pilot team initiative, explore alternative commercial structures and reward systems for the segment teams, in preparation for transitioning those teams from their performance improvement charter into the management mechanisms for their segments.
6. Once a segment team has achieved a minimum PPC of 85%, attack cycle time by having the team produce a pull schedule for the activities within its segment. Set a target cycle time to be met or bettered of 6 days per segment, equivalent to a 24 day cycle from frame start to closing (note that no additional time is allowed for closing beyond the physical building activities). Spend the subsequent quarter achieving the team target, then adjust the standard schedule template. Target date for a pilot segment cycle time of 6 days is within 10 months of start.
7. Once the pilot team is clearly moving toward its 6 day target, form teams for the remaining segments, including Foundation. Help the new teams replan their segment activities with pull scheduling, again with the 6 day target. It may also be appropriate at this time to initiate whatever steps have been agreed regarding the commercial structure and reward systems for segment teams.
8. Train the teams how to do time studies of activities, so they can further reduce cycle time each subsequent quarter. Also explore opportunities to cross train team members. Each quarter, each segment team implements time studies and cross training to reduce segment cycle time by a minimum of 1 day, with a mid-term target of 16 days from frame start to closing to be achieved within 18 months, plus a cycle time for Foundations of 4 days (Foundation cycle time is treated separately because of the need for maintaining a backlog of foundations to buffer against weather delays).
9. Extend improvement efforts upstream into pre-Foundation activities, initiate exploration of product design changes that reduce cycle time or have other advantages for the build cycle, complete the transition to segment teams as the commercial unit, and deploy this structure and approach to all industry partner locations.

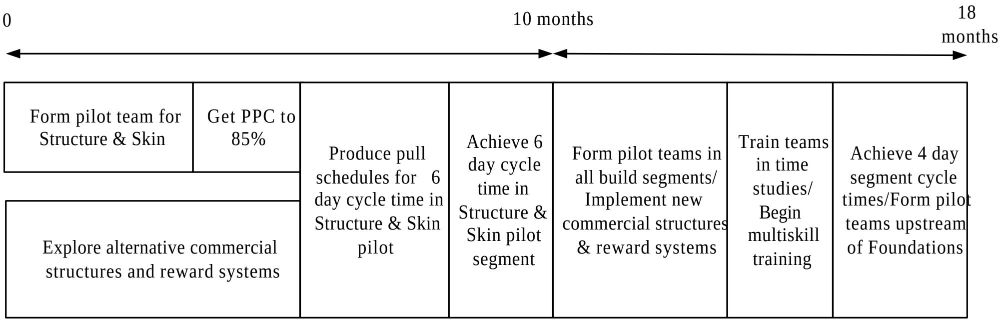

Figure 3: Implementation Schedule

SUMMARY OF HYPOTHESES TO BE TESTED AND ISSUES TO BE EXPLORED

- The best way to organize is in teams based on dividing the activities in the delivery cycle of a home into segments that take approximately the same amount of time and include within their boundaries the various systems that make up the home.
- Work flow reliability can be improved to a sustained level of 85% or better.
- Segment teams can learn to be self managing.
- Craft workers can be taught multiple skills, both within their trade and across trades.
- Multiskilled craft workers will increase the reliability of segment delivery to schedule.
- Multiskilled craft workers will allow reductions in segment cycle time.
- Segment durations can be balanced by shifting tasks between segments, thus creating a type of ‘construction assembly line’, which can accommodate homes of different durations.
- Recovery of homes that fall off the even flow schedule can be reduced to one week by maintaining an appropriate level of slack in segment durations, by improving trade contractor production management systems, and by judicious use of overtime.
- The build cycle for a home can be reduced to 16 days or less from frame start and sustained indefinitely.
- Material suppliers will cooperate to reduce lead times and eliminate variations in delivery and quality needed to reduce cycle time.
- Team pull scheduling can be used to overlap activities within each segment, thus reducing cycle time.
- Time studies can be used to reduce the duration of activities within each segment, thus reducing cycle time.
- Productivity can be increased consistently with reductions in cycle time; i.e., fewer labor hours will be required to do the work of each segment.
- What is the best commercial structure for the segment teams?
- What is the best worker compensation structure for the segment teams?

- What are the measured benefits to all participants of EFP/CTR?

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