TAKT-TIME PLANNING AND THE LAST PLANNER

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ABSTRACT

Introduction of the Last Planner™ System helped to improve predictability and overall productivity in the construction industry. In manufacturing, the use of takt-time resulting in production to a set beat, has long been a center piece in leveling work flow and optimizing production lines. This paper will explore how we successfully merge the rigorous and more pre-determined structure of takt-time planning with the fluid, more interactive and responsive Last Planner™ System. The paper will use the Cathedral Hill Hospital Project as an example of takt-time planning in use and describe how the production team can work together with Last Planners to make sure that the structure and alignment from the takt-time plan also improve and simplify the Last Planner's ability to plan their work successfully. We are especially interested in the dynamics around worker buy-in and the notion of manageable 'chunks' of work to improve the ability for workers to plan successfully.

KEYWORDS

Takt-time planning, Last Planner™ System, production system design

INTRODUCTION

Production system design in construction is inherently complex, for the production system is project-based with a dynamic team of individuals trying to create a unique product in a fixed amount of time. As such, the theory to help project teams solve production system design problems should aim to be more prescriptive (Rooke et al. 2012). This paper identifies how takt-time planning contributes to production theory by providing a method for work structuring around the principles of continuous flow and production leveling using the four language games described by Rooke et al. (2012). This approach to work structuring aligns with the two-part lean implementation strategy outlined by Ballard and Howell (1998).

Takt-time planning is possible with the use of a production control system like the Last Planner™ System, which has proven to increase plan reliability and create the environment for continuous improvement to take place (Ballard 2000). This paper examines how takt-time planning expands the Last Planner™ System. The paper also

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presents an example for how takt-time planning is used at a hospital in San Francisco, California, and sets up future case-study research at the hospital on takt-time planning. Planning began in the design process and reveals the strength of identifying production strategies early on in order to influence design.

BACKGROUND

WHAT IS PRODUCTION THEORY?

Using Wittgenstein's metaphor of language games, Rooke et al. (2012) identified four language games with the intent of improving the understanding of production theory. The first language game is **production science**, which relates to creating optimal flows of work in a stochastic environment. Variation and lead times in this language game are solved with mathematics. The second is **network of commitments.** Network of commitments is a game generated from Toyota production system (TPS) principles: respect for humanity, develop your people, and a value on the long-term. In the Last Planner™ System, the construction schedule is a network of commitments. The third is **Knowledge**, which relates to the principles of genchi genbutsu, learning through action, and organizational knowledge (Liker and Meier 2006). The **knowledge** language game also includes the Shewhart/Deming cycle (Deming 1986). The fourth is **benefits**, which identifies the values of the internal and external customers in the production system.

LAST PLANNER™ SYSTEM

The Last Planner™ System increases plan reliability by decomposing planning into distinct processes that focus on different levels of detail (Ballard 2000). The rationale for splitting up project planning is that the further out one plans, and the more detail one plans to, the more incorrect the plan will be. In addition, as the plan unfolds and it becomes known who will be doing what work at the same time or before/after others, through collaboration one can obtain input on alternative plans, and subsequently commitments from those doing the work. In a way, each process level developed as a counter measure to the different problems that surfaced during the creation of Last Planner™ System.

The first objective in the Last Planner™ System is to identify what **should** be done via the Master Scheduling and Reverse Phase Scheduling (RPS) meetings (Ballard and Howell 2003). The Master Schedule identifies the milestone dates for the project. The focus of the RPS meetings is to pull plan to the milestones in order to validate the schedule. The purpose of working backwards from the end and pulling the work is that this helps identify the work that releases work to others. The RPS meetings also validate the Master Schedule and identify the allocation of float in the schedule.

The second objective is to turn the work that **should** be done into work that **can** be done through the make ready process. Ballard and Howell (2003) identified three categories of constraints for activities: (1) directives, (2) prerequisite work, and (3) resources. Directives are the information required to produce the desired output (e.g., design documents, specifications, task assignments, etc.). Prerequisite work consists of the work required that must be completed before the activity starts. The resource constraints are labor, equipment, and the space required to perform the activity. Koskela (1999) provides seven similar pre-conditions to any construction activity: (1) design, (2) components, (3) materials, (4) workers, (5) space, (6) connecting work, and (7) external conditions. Work is made ready by creating a lookahead schedule of the upcoming six weeks of schedule activities and performing constraints analysis. If an upcoming activity has a constraint (in any category mentioned) then that constraint needs to be tracked and solved proactively in order to eliminate potential schedule impact.

The final planning objective is to commit to work that will be done via the commitment meeting. The commitment meeting first identifies work that **should** be done and **can** be done. The Last Planner, the individual who will be in the field directly managing or performing the work, commits to completing the assignment. This is the work that **will** be done. Quality assignments should meet five criteria: (1) definition, (2) size, (3) sequence, (4) soundness, and (5) learning. In summation, the Last Planner™ System identifies what work **should** and **can** be done, then tracks the commitments for what **will** be done and what was done (**did**) (Figure 1: Overview of the Last Planner™ System (Ballard and Howell 2003).

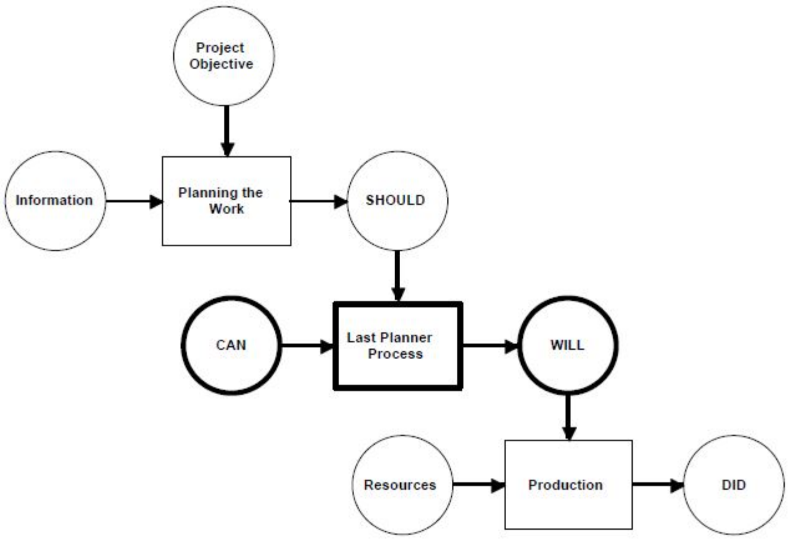

Figure 1: Overview of the Last Planner™ System (Ballard and Howell 2003)

TAKT-TIME PLANNING

The word 'Takt' is German for the word 'beat.' Takt-time is "the unit of time within which a product must be produced (supply rate) in order to match the rate at which that product is needed (demand) rate" (Frandson et al. 2013). The objective of takt-time planning is to help create a more stable environment for the Last Planner™ System by actively designing continuous workflow for trade activities wherever possible. The Last Planner™ System provides the control mechanism and stability of the production system. In the context of the Toyota Production system's continuous improvement spiral (Figure 2), the Last Planner™ System supports the step of 'stabilizing' and takt-time planning provides the means of 'creating flow' (Liker and Meier 2006).

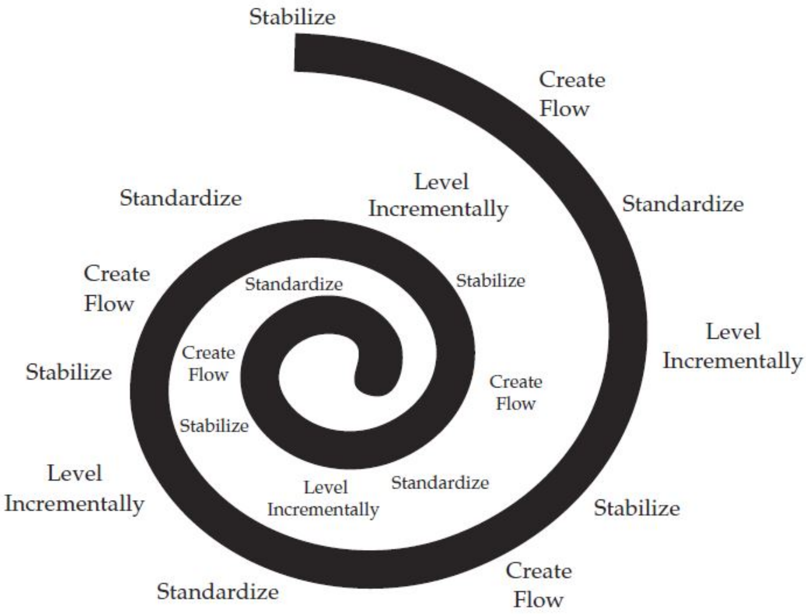

Figure 2: Continuous improvement spiral (Figure 3-4 in Liker and Meier 2006)

Takt-time planning is a work structuring method. Work structuring is a part of production system design that answers the following questions (Ballard 1999):

1. "In what chunks will work be assigned to specialists?"
2. "How will work chunks be sequenced?"
3. "How will work be released from one unit [one trade crew activity performing an activity] to the next?"
4. "Where will decoupling buffers be needed and how should they be sized?"
5. "When will the different chunks of work be done?"
6. "Will consecutive production units execute work in a continuous flow process or will their work be de-coupled?" (Tsao et al. 2000)

Takt-time planning develops answers for these questions over an iterative six-step process: (1) data gathering, (2) zone definition, (3) trade sequence generation, (4) individual trade duration, (5) workflow balancing, and (6) production schedule finalization (Frandson et al. 2013). More steps may be necessary, however, as the iterative process begins with a general production strategy, develops into a rough production plan, then becomes a finalized schedule for production. This 'rough' to 'fine' distinction is similar to the process design steps outlined by the white paper "Aiming for continuous flow" (Ballard and Tommelein 1998). In relation to the triads of the Lean Project Delivery System (LPDS) (Figure 3), takt-time planning should begin in the early project definition phase of a project because it is a work structuring method (Ballard and Howell 2003).

Using the four language games, it is clear how takt-time planning fits into production theory. Takt-time planning uses **production science** to establish continuous flow where possible and to manage buffers in the form of additional crew capacity. The process requires a long-term philosophy of developing the capability of all team members, as well as understanding the importance of production planning as early as possible. A successful production plan developed from takt-time planning is possible only through systems thinking and effectively managing the **knowledge** of the entire team. Last, the **benefits** and costs of all stakeholders identify the conditions of satisfaction and trade sequence.

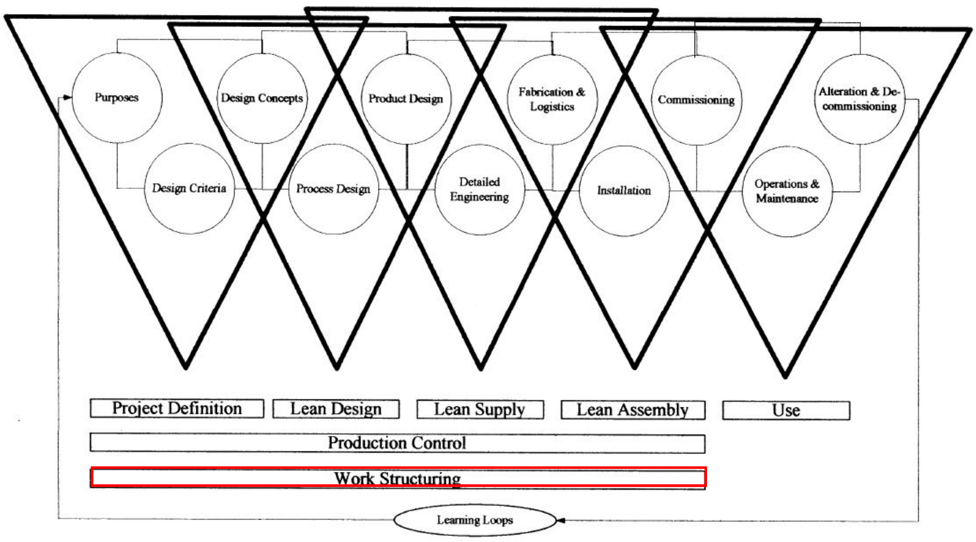

Figure 3: Triads of the Lean Project Deliver System (LPDS) (Ballard and Howell 2003)

TAKT TIME PLANNING AND THE LAST PLANNER™ SYSTEM

COMPLEMENTS

Takt-time planning and the Last Planner™ System complement one another in many ways. Overall, takt-time planning expands the Last Planner™ System by introducing continuous flow and more standardized work for the Last Planner™ System to control to, and the Last Planner™ System provides the mechanism for control and facilitates planning and adaptation where continuous flow is not possible.

TAKT-TIME PLANNING

Beat: Takt-time provides the project with a feasible beat and work flow that meets the customer's demand rate, at a minimum. If the customer demand rate for a phase is flexible, then the production team can create the demand rate for the phase. This provides two benefits. First, beat provides activities of the correct size and sequence to the Last Planner as well as a clear outlook on upcoming work. Second, a planned workflow reduces stress on the foreman who may otherwise worry about the flow of the job for the company s/he works for because his target is clear: as long as s/he is on track for completing the small batch of work assigned in the takt-time cycle then s/he is on track for the entire job. However, a planned workflow may also increase stress on the production system because a set beat is likely to surface (new) production problems.

Increased focus and standardization of the lookahead process: takt-time planning provides staff with focus and priority for their work on site. The lookahead process is simplified to standardized, clear batches of work.

Increased common understanding: Common understanding is considered the 8th flow, augmenting Koskela's 7 flows in construction (Pasquire 2012). Common understanding is the result of engaging team members with a purpose. Engagement without meaning results in confusion. Takt-time planning provides the opportunity for the entire production team, from detailers to foreman in the field, to develop a common understanding on the overall production strategy. In the field, a set takt-time helps develop a daily goal for workers to meet. This enables a minimum daily calculation of output to stay on track because the takt-time planning process already planned the production system around chunks of work being released at even intervals. In addition to the daily goal, takt-time also serves the function of adding purpose to the work performed and provides the workers with clarity on where they will be working next. For detailers, a common understanding of the production strategy enables them to design for takt-time, not only constructability and coordination.

Increased urgency for make ready analysis: Takt-time increases the urgency for make ready analysis because failure to do so will immediately affect an entire 'Parade of Trades' (Tommelein et al. 1999).

Reduces scope of pull planning: The sequences of work through areas planned to takt-times are generalized, so the scope of work that needs to be pull planned is reduced to 'one off' pieces of work (e.g., operating rooms, imaging rooms, kitchen areas, etc.).

Identifying 'schedule noise' vs true 'schedule variance': Takt-time plans separate scheduled task variances in the commitment plan into schedule noise and 'schedule variance.' Schedule noise is defined as the temporal movement of a task within a given takt-time sequence that does not affect the completion of work within the takt-time sequence. Schedule variance is defined as the temporal movement of a task within a given takt-time sequence that shifts into another takt-time sequence. If a task moves into another takt-time sequence, then it means that it is in conflict with another trade activity and requires communication to either: (a) work out the conflict in the field without affecting the incoming trade (known as a soft conflict), or (b) a replanning of the work because the current schedule will result in a delay of work for the incoming trade (known as a hard conflict). Figure 4 shows an example of work for a given activity divided into smaller tasks, represented as bars. A few tasks may shift around and create 'noise,' but only one task requires the production team to communicate and actively solve the problem.

There are two benefits to distinguishing schedule noise from schedule variance. The first is that it reduces stress on production team members, for the distinction reduces micro management and reduces the waste of resources on solving small schedule changes that do not actually affect the overall schedule. From a management cybernetics perspective, this means that takt-time acts as an 'attenuator of complexity.' (Espejo and Reyes 2011). The second is that takt-time planning creates a new perspective on Percent Planned Complete (PPC) metrics. Takt-time planning values a PPC metric that measures the handoff of work at the correct moment in time instead of the daily fluctuations in the schedule that are sometimes measured via the PPC metric. From a lean thinking perspective it is important to root out and solve problems; nevertheless, distinguishing task fluctuations that impact the overall schedule and those that do not is important for project execution.

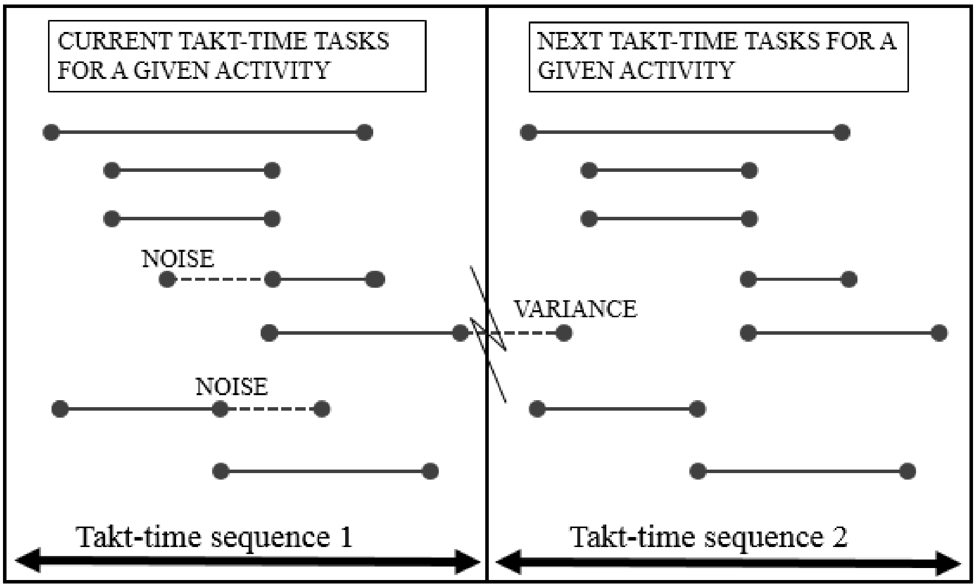

Figure 4:'Schedule noise' vs. 'schedule variance

LAST PLANNER™ SYSTEM

Facilitates irregular work variances: The Last Planner™ System complements takt-time planning by facilitating irregular work variances, defined as areas of work where continuous flow is infeasible. The Last Planner™ System accounts for 'go-back' work as well as work in specialized access areas, and it accounts for work in process.

Facilitates low level variation: The make ready process and commitment planning provide the mechanism to adapt to variation at the operation level. The PPC metric accounts for some of this variation as it affect execution of the work. While the takt-time planner would consider the variation 'noise' if it does not affect the hand-off of work, the Last Planner™ System is the means to obtain the data.

Provides control system: The Last Planner™ System provides the mechanism to facilitate takt-time planning. Takt-time planning is the process of sequencing and leveling production through similar areas of work, but it still requires a means to control the production schedule.

Engages workers: The Last Planner™ System is a system that engages the foreman, the Last Planner, in the actual planning of work. The Last Planner is encouraged to offer practical wisdom and also reject assignments that do not meet the five quality criteria.

CASE STUDY OF TAKT-TIME PLANNING IN USE

PROJECT BACKGROUND

The Cathedral Hill Hospital (CHH) is an approximately $1.2 billion dollar hospital project in San Francisco, California. The project started its first design phase in 2005. The hospital is now 12 floors tall and accommodates 274 patient beds. Construction of the interiors is scheduled to start in the fall of 2015. The boundaries for this takt-time planning effort are from poured concrete floors to final inspection after all the finish work is installed. Takt-time planning at CHH started in the summer of 2013, and began by identifying the initial production strategy. The project is an example of an entire production team collaborating early on to execute a project using Lean construction principles.

PRODUCTION PLANNING

The production planning team consists of the production manager, inspector of record (IOR), project general superintendent, and the electrical-, fire sprinkler-, drywall-, plumbing-, and mechanical trade partners. The team meets weekly for approximately two hours. The trade partner superintendents are always at the meeting and their detailers come to the meetings when necessary. The team has as objective: establish the production plan for the project.

The current production strategy is to split the interior work into three phases: (1) the overhead phase, (2) the in-wall phase, and (3) the finishes phase. The floors will split into quadrants during the overhead phase and into twelve areas during the remaining phases of work. The planned takt-times are three weeks for the overhead phase, one week for the in-wall installation phase, and one week for the finishes phase. Figure 5 demonstrates how the different Parades will move through the building.

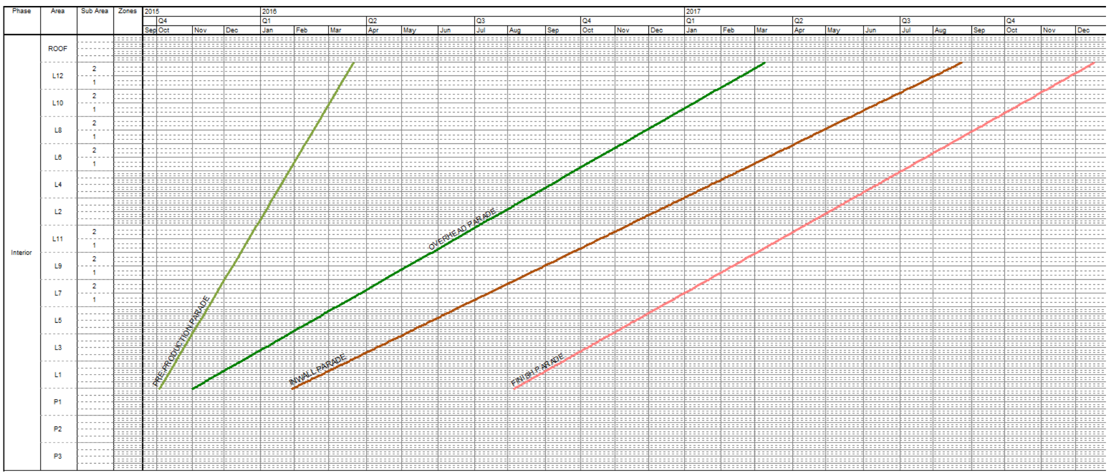

Figure 5: Summary level of the interior production strategy in Line of Balance format (Vico 2009)

Establishing the production plan is on-going. The team began with each trade partner presenting their typical work methods. Upcoming tasks for the production team are the following:

- Establish the areas of work for the in-wall rough installation and finish Parades
- Validate the production strategy (identify trade sequence, phases, takt-time durations, fabrication and spooling times, and zones) for takt time
- Identify the conditions of satisfaction for each trade activity
- Identify and quantify the total amount of workable backlog outside of the takt-time plan
- Identify the current buffers in capacity
- Identify opportunities for innovation and the last responsible moment (Lane and Woodman 2001) to implement them

The target for the team is to create a production schedule that provides continuous flow to the most trade activities across the entire project during interior construction. This requires that the production team create an initial detailed production strategy in order for detailers to design for production, similar to how manufacturing designs for assembly (Boothroyd 1994). The production strategy is communicated through line of balance schedules using Vico, charts in Microsoft Excel, and Gantt charts created in Primavera P6 (Vico 2009; Microsoft 2013; Oracle 2013).

Takt-time planning on this project is still in its development phase. The purpose of this section of the paper was to share production system design knowledge learned thus far on the project by identifying how takt-time planning is used on-site and explain how it will expand the implementation of the Last Planner™ System on the project. As such, this paper also frames future case study research on takt-time planning at the CHH and other projects.

CONCLUSIONS

This paper set out to accomplish three tasks. First, it situated takt-time planning in the context of production theory using the four language games. Second, it identified how takt-time planning and the Last Planner™ System complement each other. Third, it provided as example of how takt-time planning is used in practice. Takt-time planning is an attempt perform work structuring and identify a feasible production strategy that can maximize the number of production activities performed with continuous use of resources. This is possible by applying LPDS and TPS principles, and by taking advantage of the environment the Last Planner™ System provides. As seen from Liker's continuous improvement spiral, there is still a long path ahead for improvement in project-based production system design. Takt-time planning is an attempt at taking a step in the right direction.

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