DEVELOPMENT OF A TAKT-TIME PLAN: A CASE STUDY

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ABSTRACT

Takt time is a design parameter used in production settings, be it manufacturing or construction, tuning the rate of work output to the customer’s rate of demand. Recent industry experiments have shown that takt-time planning and execution of construction work can yield significant benefits in regards to time savings, money savings, improved quality, etc. In this paper we describe our action-research implementation of takt-time planning by means of a case study on an approximately $2.5 million retrofit of a floor in an operating healthcare facility. We illustrate the takt-time planning process using excerpts from one-on-one meetings with subcontractors on the integrated project delivery team. The commercial terms combined with these subcontractors’ willingness to express flexibility in their means and methods, as well as sequencing of work, made it possible to trade off pains and gains among team members for the sake of optimizing the project’s takt-time plan. We situate the takt-time planning process in the context of the levels of the Last Planner System, comprising Master Scheduling, Reverse Phase Scheduling, Make-ready Planning and Commitment Planning. Execution of the take-time plan is underway. We conclude that takt-time planning helps to pose many questions that must be answered in production system design.

KEYWORDS: Takt-time planning, Production system design, Line of balance, Lean project delivery

INTRODUCTION

This paper reports on experiments with takt-time planning at Sutter Health’s Palo Alto Medical Foundation (PAMF), where it was used to plan the retrofit of a floor in an operational healthcare facility. The project is delivered by an integrated team of designers and contractors, with commercial terms spelled out in an Integrated Form of Agreement (IFOA) contract (Lichtig 2006). Accordingly, the team is using Lean Project Delivery.

Takt time is a design parameter used in a production setting be it manufacturing or construction that paces the production rate to match the rate of customer demand, without exceeding it (Hopp and Spearman 2008). Takt time is defined as: “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).
Pacing activities to specific rates in construction is not a new concept. During the construction of the Empire State Building (1929 to 1931) four activities (steel erection, concrete flooring, exterior metal trim, and exterior limestone) were set as the ‘pacemakers’ for the construction of its 102 floors (Willis and Friedman 1998). The line of balance has also been used for decades in pavement- and in commercial construction (Arditi and Albulak 1986, Seppanen and Aalto 2005, Kemmer et al. 2008). More recently the US housing industry has been using demand management techniques and ‘even-flow production’ to maintain resource continuity and reduce lead times (lead time and cycle time are sometime used with opposite meanings) (Ballard 2001, Wardell 2003, Bashford et al. 2004, Yu et al. 2009).

Takt time in construction has shown up more recently in literature, starting with home building in the United States (Wardell 2003 and Velarde et al. 2009) and highway construction in Ecuador (Fiallo and Howell 2012). More recently takt time was used to develop schedules for production on a hospital project in California (Linnik et al. 2013 and Frandson et al. 2013) and to standardize work on a residential construction project in Brazil (Mariz et al. 2013).

The purpose of developing a takt-time plan is to translate the construction schedule, known as a Master Schedule in the Last Planner System™, into a schedule for production. A benefit of takt-time planning is that it engages project participants early in conversations focusing on the details of how work can and will be performed.

The development of the takt-time plan is a six-step iterative process that produces a schedule of production based on an actively designed production system (Frandson et al. 2013). The production system in this circumstance is project-based with a temporary organization and includes the work methods, contract structure, and all of the technology used to produce the retrofitted floor for the customer. The production system is actively designed because those who are specifically involved, the subcontractors (trade partners) performing the work, are engaged from the very beginning of the process and are asked questions as to how they would like to perform the work and the resource implications for performing the work with different crew sizes and in different sequences. When all this information is known for a given sequence of work, the team can create and commit to a production schedule that considers each trade’s personal constraints and maintains an amenable flow of work for everyone.

This study focuses on the development of the takt-time plan for the overhead phase of work on this project. The overhead phase begins with framing at priority walls (Mikati et al. 2007) and ends with the overhead inspection. This development and lessons learned from applying the six-step process to plan the overhead phase is the focus of this paper.

**PROCESS FOR DEVELOPING A TAKT-TIME PLAN**

**Steps in takt-time planning**

Frandson et al. (2013) defined and detailed six steps in the takt-time planning process. Though the steps are listed in sequential order, the authors emphasize that the implementation of takt time requires iteration: (1) Gather information, (2) Define areas of work (zones), (3) Understand the trade sequence, (4) Understand the
individual trade durations, (5) Balance the workflow, and (6) Establish the production plan.

**Takt-time planning and the Last Planner System™**

Takt-time planning is iterative and involves conversations to reveal the conditions different production team members prefer to work with: their means and methods, preferred sequence, desired workflow, and durations (given a crew size, specific project design, and including the work the subcontractors anticipate having to complete on other projects). The conversations with the team also reveal the assumptions made in their initial planning and alternatives to how each trade can perform the work.

In this case study, the team chose to begin takt-time planning before Reverse Phase Scheduling (RPS). Doing so provides time for the team members to understand their work and realize their trade sequence alternatives before the trade sequence becomes more fixed in the RPS process. Sequencing information is needed for RPS anyway, but thanks to takt-time planning it is revealed sooner and different sequence alternatives can be traded off based on a shared understanding of pains and gains for each trade. After a team meeting, the superintendent remarked “we have never talked to the subs before having given them a schedule.”

Takt-time planning fits into the Last Planner System™ before RPS because it addresses work structuring: it makes people think through how the job can be broken apart into batches of work that trade partners can pull-plan to in the RPS meeting. Selection of a takt time and the corresponding zones may follow these guidelines: The takt time and zones must be big enough for the trades to work through productively, yet small enough to control to frequently (e.g., at a daily interval). The zones must allow for trades to fully complete work and flow in a logical sequence. This level of detailed planning also serves as a check against the initial assumptions used in the Master Schedule. Definition of the Master Schedule’s milestones sets the demand rate for the job, so the proposed takt time for each phase of work must set a pace that meets it. In this case study, the initial Master Schedule did not set the demand rate for each phase; the objective of the takt-time planning was to create a fast-paced, feasible production schedule.

Takt-time planning also suits more detailed levels of the Last Planner System. A takt-time plan sets the locations (zones) in advance that need to be made ready, providing a clear lookahead into future work for each trade. The takt time also helps team members create quality assignments during commitment planning. Quality assignments meet five criteria: definition, size, sequence, soundness, and learning (Ballard 2000). Takt-time plans begin to indicate the definition, size, and sequence for assignments to be committed to, allowing Last Planners to focus on identifying the soundness of each assignment (Is the prerequisite work done? Are the required materials on hand? Is the design complete? Etc.). As for learning, because zones are clearly delineated by task, it becomes clear to all whether or not work is progressing as planned.
TAKT-TIME DEVELOPMENT FOR OVERHEAD PHASE

The takt-time planners and the superintendent met one-on-one with each trade partner involved in the overhead phase (drywall, fire sprinkler, piping and mechanical systems, electrical, and plumbing). In each 2-hour meeting, the trade partner marked up the scope of work while describing desired sequences. In this phase, the drywall partner had work at the core shaft walls which released work to the MEP partners. The fire sprinkler partner’s desired workflow was to complete full lines of work, but from these preliminary meetings it was identified that this work, with the exception of a few locations, would have to be performed in the finishing phase because the fire sprinklers must drop into the center of the ceiling tiles.

The piping- and mechanical partner identified what they could do on each day of work, given their desired sequence, from the very beginning (Figures 1 and 2). This level of detail was helpful, as it showed how they wanted to work, and how much work they could perform in a day given their preferred sequence and crew size. The sheet metal foreman was able to provide a color-coded floor plan of the duct work as well as a desired sequence and the corresponding durations for each activity.

The electricians divided their work into quadrants with durations calculated from a task list at a greater level of detail than the Master Schedule, and also provided the location of all their overhead work. This level of detail differed from that of the piping and mechanical partners’ detail (broken down daily and in much smaller sections) and therefore posed some planning challenges. The crew sizes and durations were specific to the quadrants only and could not be reduced and reconfigured into different zones. Detail was lacking on how the work would be performed in the area (e.g., does the electrician need the whole space for the whole time frame or will the quadrant be worked through progressively?) and for what duration. This resulted in two additional rounds of follow-up questions in order to understand what type of zone configuration was suitable for their work. Overall, their desired workflow was to work out from the electrical room and fully complete each quadrant in one pass because of how the electrical work was designed.

After meeting with each trade partner, a tentative takt-time plan was produced. The scope of the follow-on RPS meeting was to first review what workflows and information each team member shared, then schedule the overhead
phase of work per the zones created from the individual trade-partner meetings. Figure 3 reflects the floor divided into six zones each with a takt time of two days. These zones were agreed upon by each team member in the meeting.

An important observation when scheduling the work to these takt times and zones was that the trades do not exactly go through each zone on a two-day cycle. Depending on the project’s design (work contents), some trades flow through each zone versus others through only some zones, and some trades need multiple takt times in a given zone. Nevertheless, the two-day takt time was used to pace the work and manage the space by allowing trade partners to claim areas of work (zones) for fixed amounts of time. It also allowed the trades to identify the zones they would like to work in first and what they are able to accomplish in the time frame. Overall, the takt time imposed a sense of urgency and detail that proved useful in the RPS meeting.

Figure 3 – Zones for overhead phase

Two optimization meetings followed the initial RPS overhead meeting to validate and improve the schedule. Line of balance techniques using Vico’s Control 2009 software helped visualize the flows of work and identify areas to improve the schedule. In each meeting, the workflows were presented to the team members showing the overall line of balance schedule for the phase and their individual flows of work (in order to demonstrate that their preferred sequence was used and the work was continuous for each trade) (Figure 4).

The initial overhead-phase schedule required 45 days to complete. The final, validated overhead-phase schedule required 44 days, contains an additional task, and reflects some re-sequenced work in order to create better flows of work for team members. The team also identified opportunities to improve the total duration of the phase during construction. One opportunity was for the electrician to work in zone 6 as workable backlog when the zone is unoccupied halfway through the project (visualizing the schedule, as shown in Figure 4, helped the team identify this opportunity).
LESSONS LEARNED

Takt and the Reverse Phase Schedule

Two logistics-related lessons were learned from using takt-time planning in the RPS meeting. First, applying takt time in the overhead phase with six zones meant that every team member needed to create an activity tag to show work in every zone. Because the zones were revealed at the beginning of the first overhead RPS meeting, more time was spent writing activity tags than originally expected. The second logistics lesson learned was that the takt time needs a visual representation in the form of vertical lines on the board so that everyone can place their activity tags in an order that maintains the takt-time sequence. In retrospect, recreating the schedule based on the pull plan (i.e., the output of an RPS meeting) without vertical lines separating every takt time meant that tasks that looked vertically aligned (i.e., the tasks occurred simultaneously in different zones) may not have been. One reason why vertical lines were not placed on the overhead phase RPS board was that vertical lines by week were already on the board (Figure 5). This caused confusion because the takt time was two days. In addition, if an activity does require two takt times, in this case four days total, it was important to place two tags to visually show that the space was occupied for those time frames. The same rule applies for activities that required multiple zones. If an activity occurs simultaneously in two zones, then it requires two separate tags.
Knowing the sequence is critical

Understanding the sequence before any takt-time plan is presented is critical, for if the sequence is not well understood, additional iteration will be needed in the development of the takt time. Understanding the sequence of trades affected by takt may not be understood until development of the RPS, so it is important to share incomplete information often with the team in order to avoid confusion.

Know what questions to ask

Two types of questions were discussed in the takt-time planning sessions: production questions and logistics questions. Production questions in this circumstance directly affect the takt time. Example questions are: “Can you mark with a highlighter where your work is and write the duration/crew size by the mark?” and “How would you divide the floor up into six equal spaces of work, and what would your duration per space be?” Logistics questions in this circumstance relate to how the work is performed. Example questions are: “Can the fire sprinkler go in before ceiling grid, or is it more effective to drop the fire sprinkler head after?”, “For which work do you require a scissor lift?”, and “What access do you require for bringing in materials to the zone?”

A relationship exists between the two types of questions, and it is important to ask both in order to identify feasible takt times and zones. Some team members were able to identify on the floor plans where their work was, their desired durations, and crew sizes; whereas others focused on logistics and how they perform the work in a general sense. While helpful, the latter set of information did not immediately help identify what a suitable takt time would be for the project phase. Thus, it was crucial to make sure that by the end of every meeting the team clearly understood from every trade partner the amount of work everyone had on the floor and distribution of where the work occurred on the floor.

Value of early conversations

Early conversations provide an opportunity to address workflow and sequence concerns on the project. The superintendent for the general contractor made the remark that they rarely have these conversations for such small projects, but definitely saw the importance in understanding the different trades’ work. The takt-
time conversations with the trade partners also revealed more of the assumptions in the original Master Schedule that was planned first. The early meetings created several instances where team members revealed how they could perform work in alternative ways that would benefit the team as a whole (e.g., the fire sprinkler partner could put in temporary sprinkler heads and drop sprinkler heads after HVAC and piping were installed in order to let them work quickly with less of a chance of damaging live sprinkler heads). In short, takt-time planning provides the setting for detailed production conversations early, in order for a project team to identify and apply the best production alternative.

Managing the CPM schedule

The general contractor noted that the number of activities and time required to enter all activities in the CPM schedule increased significantly when the details of the RPS with takt times and zones were placed back into the Master Schedule (e.g., one activity to be done in six zones now required six individual activities, namely one per zone). In addition, the logic of the takt-time plan became very difficult to understand when looking at the overall schedule as a Gantt chart. As such, the team adopted a ‘takt book’ that showed where each trade was working each day in order to ‘see’ the schedule more effectively. For further iteration on each RPS, the information was also presented in a line of balance format using Vico Control 2009 in order to visually identify opportunities for improvement. In the end, the project team, including the owner, decided that the final schedule for the project should be the schedule produced from Vico Control.

Subcontracted work vs. trade partner work

How the work subcontracted by the general contractor was scheduled to takt times differed from how the work performed by trade partners was scheduled to takt times. When trade partners had a specific sequence or constraint on how they needed to do the work (e.g., “we need to install all W6 walls first”, or “we must complete full runs of conduit, thus we need this whole space”), then that constraint became a constraint for the takt-time plan. More flexibility (seemingly) existed with how the subcontracted work would be performed and in what time frame. This was an important lesson because it revealed that takt-time planning is a process that can be performed by an integrated project delivery team, or that can be applied using a more top-down approach in a competitively-bid situation. Of course the trade-offs that could be made would be different.

Takt-time planning is iterative

One issue that team members brought up was why the pull plan in the RPS meeting had no dates. It would seem logical to use dates based on the Master Schedule (e.g., milestones) in order to limit the pull plan to a fixed duration. Thus, if the pull plan scheduled to a particular takt-time configuration does not meet the milestones, then activity durations need to be reduced. This approach might not create an optimal schedule though. In addition, one could question the validity of the initial Master Schedule. On this project, each phase was pulled to different takt-time durations and then input into CPM scheduling software as well as into Vico Control.
2009 (and in later phases, just Vico Control 2009). Activity crew sizes and duration assumptions obtained from the RPS meetings were used in different alternatives in order to find additional paths with shorter durations.

A challenge for the iterative nature of takt-time planning is that when RPSs are created to specific takt times and zones, then those schedules are somewhat fixed and require additional work to change if the takt time requires rebalancing (i.e., switching from a 2-day to a 3-day takt time) or the zones require revision.

**Boundary limits of takt-time planning**

A challenge for identifying balanced takt times on this project was that the takt-time plan did not scale across multiple floors or large areas of work, thus the minimum/maximum crew sizes and the different distributions of work for each trade at each phase made it impossible to develop a perfectly balanced, feasible schedule. Regardless, takt-time planning did reveal that the team could work together and manage the space they did have at a higher resolution (by zone rather than by the entire floor), as opposed to everyone “working all over the floor at once and fighting for space”. Thus, while the overhead takt-time plan did not produce a perfectly balanced schedule for production, it did provide a schedule that accounted for space and allowed for the team to work productively throughout the entire floor. In addition, the general contractor could now control the work contents to the schedule of production during construction.

**CONCLUSIONS**

Takt-time planning was performed on a one-floor retrofit in the overhead-, in-wall rough installation-, and the finishing work phase. This paper reflects lessons learned and excerpts from how a takt-time plan developed for the overhead phase. On this project, takt-time planning began with individual 2-hour trade partner meetings asking exploratory production questions. These meetings proved valuable, helped drive the conversation in the RPS meeting, and revealed alternative sequences for the team to perform the work. In the initial meetings with the trade partners it was critical to ask questions that clearly identified the distribution of the work contents (i.e., where is the work located, what is the crew size, and how long will it take to perform?). Last, effectively communicating to the team that both the takt time and the zones for each phase are flexible during the development of the takt-time plan is crucial.

Future research questions include: When is the best time to introduce the first iteration of a takt-time plan? Does takt time produce labor creep and, if so, does this counteract the increases in productivity? How can takt time be designed into a building and what are the effects? What level of detail should the RPS process produce?

**ACKNOWLEDGMENTS**

We would like to thank the Mill’s project team for their engagement with us in this action research. The development of the ideas presented in this paper was supported in part by gifts made to the Project Production Systems Laboratory (P2SL). All support is gratefully acknowledged. Any opinions, findings, conclusions, or
recommendations expressed in this paper are those of the authors and do not necessarily reflect those of contributors to P2SL.

REFERENCES