Title

Use of Takt Planning in Production System Design

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Introduction

Takt is the German word for "beat," referring to the regularity in time with which process steps occur. Takt planning in construction is a work structuring method used to create a predictable pace for the flow of resources across well-defined geographic locations on-site when performing similar steps in each of the areas. What constitutes "similar" is a matter of debate and ongoing research.

Takt planning may be used to synchronize the process steps that the different trades perform to complete their work in different areas of a building while aiming to create a constant flow of work and potentially also a constant flow of material and information across the supply chains.

While takt planning is a well-established method used for planning manufacturing systems, its use in construction is fairly new. Various approaches—often conceptually similar—can be used when using takt to control the pace of work in construction. In this workshop, we will cover some of those approaches.

Over the course of our two-day workshop, we will conduct a simulation designed to teach how to apply takt planning for repetitive work across similar locations in a building using the Lean Construction Management (LCM) method developed by Drees & Sommer (www.dreso.com) in Germany. Later, towards the end of day two, we will provide an overview of other takt planning approaches including several used in practice today in the San Francisco Bay Area, and one being researched by P2SL that uses "work density" as the basis for takt planning of non-repetitive work (i.e., when the nature of work varies by geographic location). We also have assembled a package of reference material into a separate handout that describes some of those approaches in detail.

In this paper, we adapted the terminology of the LCM system to the Last Planner® System (LPS) steps commonly used in the United States (Figure 1).

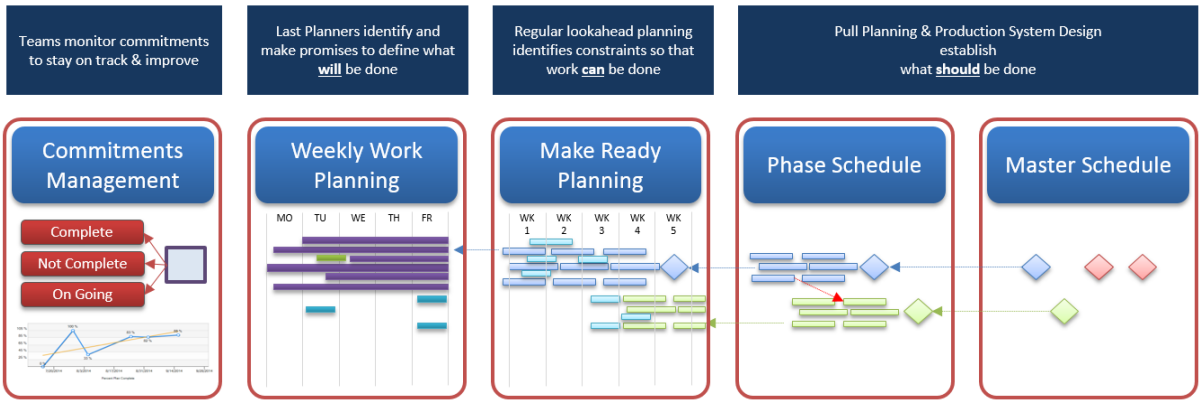

Figure 1: Last Planner® System Components

Takt planning in the LCM approach operates at the phase schedule level. A takted process can be seen as a sequential "train" of trades, comprising standardized process steps running through the construction site with leveled resources (Figure 2).

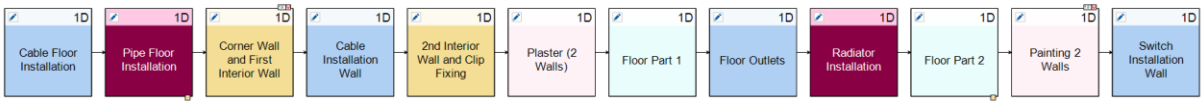

Figure 2: Standard Process Steps at a Given Location

Defining Takt Areas

It is important to note that while not all areas of a building can be represented using similarly sized geographic areas, in each project areas can be found that can be planned using the takt approach. Takt planning has been used on a wide range of projects, for example, to optimize complex construction projects like power plants or big cruise ships (e.g., Heinonen and Seppänen 2016). It has also been applied successfully to projects where work is non-repetitive (e.g., Linnik et al. 2013, Dunnebier et al. 2014).

Takt Planning and Conventional Scheduling

As a major difference with how conventional construction scheduling (e.g., using the Critical Path Method (CPM)) is done, when using takt planning the overall work within a phase is divided into smaller batches that are planned and controlled in the defined takt location (zone) with a well-known sequence to achieve a predictable pace (so-called "work flow"). This has a beneficial overall organizational effect on the trades and the way they approach the planning of their work both off-site and on-site. Takt planning defines rules regarding how the trades move from one location (zone) to the next. For the duration of a takt, only one trade is allowed to perform work in any one zone, which means that they can work there without disturbance from other trades. When a takt ends, the trade is expected to have finished all work in their designated zone, vacate that zone, and move to the next zone where they are designated to work, while the follow-on trade moves into the vacated takt zone.

In conventional scheduling, work flow decisions (if decided at all) are usually implicit in the lag duration between activities, lacking the detail of who will be performing what work, where, in which sequence, and at what time. Since conventional scheduling has no clear process to define such items, it is left the various trades to decide on their timing and level of planning detail. All too often, those decisions are made too late and lack the systematic process that is followed when using a takt planning approach.

Takt planning provides a disciplined method to work structuring and management of work flow. The most common challenge when implementing takt planning on projects is to get the team to follow the takt plan. Extensive use of CPM over the years has resulted in short-sighted and opportunistic behaviors during work execution. Teams must learn to resist the conventional

wisdom of pushing resources to perform work as soon as possible and whenever they spot a near-term opportunity. They need to learn to trust that the disciplined pull approach achieved through takt planning will result in more predictable execution than what they may be used to, and they need to learn to plan for workable backlog so they can take advantage of available capacity should some be freed up during execution. Takt planning offers a systematic process to adjust the overall takt flow at the phase schedule level so that teams can maintain alignment between what they should do in the near-term and what they should do for the long-term.

Takt Planning and the Line of Balance Method (LoB)

Takt planning and Line of Balance (LoB)(e.g., Lumsden 1968, Harris and Ioannou 1998) methods are conceptually similar in the sense that they are used to manage the flow of resources while performing similar work across geographic locations (or other repeated units). However, they differ in the control methods used to set the pace of the work. Some takt planning methods aim to maintain flow by adjusting crew sizes to perform similar successive steps in the various zone within a fixed unit of duration (namely the takt). However, when implementing LoB, the duration a crew spends in a given location varies based on their production rate and the quantity of work they perform at that location. Essentially, in takt planning buffering is done with capacity, while in LoB buffering is done with time (Frandson et al. 2015).

When to do Takt Planning?

Takt planning is performed in preparation for and during the phase scheduling phase of the Last Planner® System (LPS). The phase schedule is the step that translates "what" needs to be done as specified in the master schedule, into "how" it will be done by the trades that are involved in the phase, individually and in concert with one another. For any given phase, presumably, several alternative phase schedules can be developed. The question is then: what criteria to use to select one from those alternatives? This is where takt planning plays a role.

The creation of a takt plan is not a single event: takt plans are living documents. Takt planning may start as soon as the project starts or sometime later, depending on what is known and when about the work to be done (e.g., management's familiarity with managing projects of the complexity they face), who exactly will be involved, and how they may go about it. Takt planning methods also vary depending on the project commercial terms and delivery approach being used. For example, when using a Lump Sum (LS) or a Guaranteed Maximum Price (GMP) contract, an initial high-level view of the takt plan can provide clarity to the trades bidding on work, concerning when and where they are expected to be on-site, so that when they propose on work, they can make assumptions to conform to that plan. This notwithstanding, once the trades are selected to work on a phase, prior to starting that phase they should collaboratively review the takt plan and update it to reflect their understanding of the work and improvement opportunities they may see. In contrast, when using an Integrated Project Delivery (IPD) approach, key subcontractor trades will have been selected early on and can actively participate in the creation of the first- and subsequent takt plans.

During work execution, the team may find that they progress at a pace faster or slower than the pace specified in the takt plan. They must then collaborate to adjust the takt plan using that real-time feedback. They may change their crew size to maintain takt or change the pace of their work by modifying the takt or zone boundaries, by resequencing takt zones depending on roadblocks encountered, or they could adjust all of the above.

Who is responsible for Takt Planning?

Takt planning is a collaborative process, but given its importance in organizing the work within phases, it is strongly recommended that clear responsibility be assigned to managing it. It should be the responsibility of the "production planner," who works at the interface between the CPM scheduling team and the Last Planners.

Implementing Takt Planning using the LCM Method

Outlined below are the main steps of the LCM method. Two main steps are taken at the start of the project during phase scheduling, namely (1) the Overall Project Analysis and (2) the Takt Analysis:

1) **Overall Process Analysis (OPA):** This is a one-time analysis that aims to (1) identify the different work areas, the so-called "zone types" that tend to correspond to phases in the building, and (2) define the process steps and sequence of trades within the each of the zone types. Examples are: the enclosure phase, the rough-in phase, and the finishes phase (Figure 3).

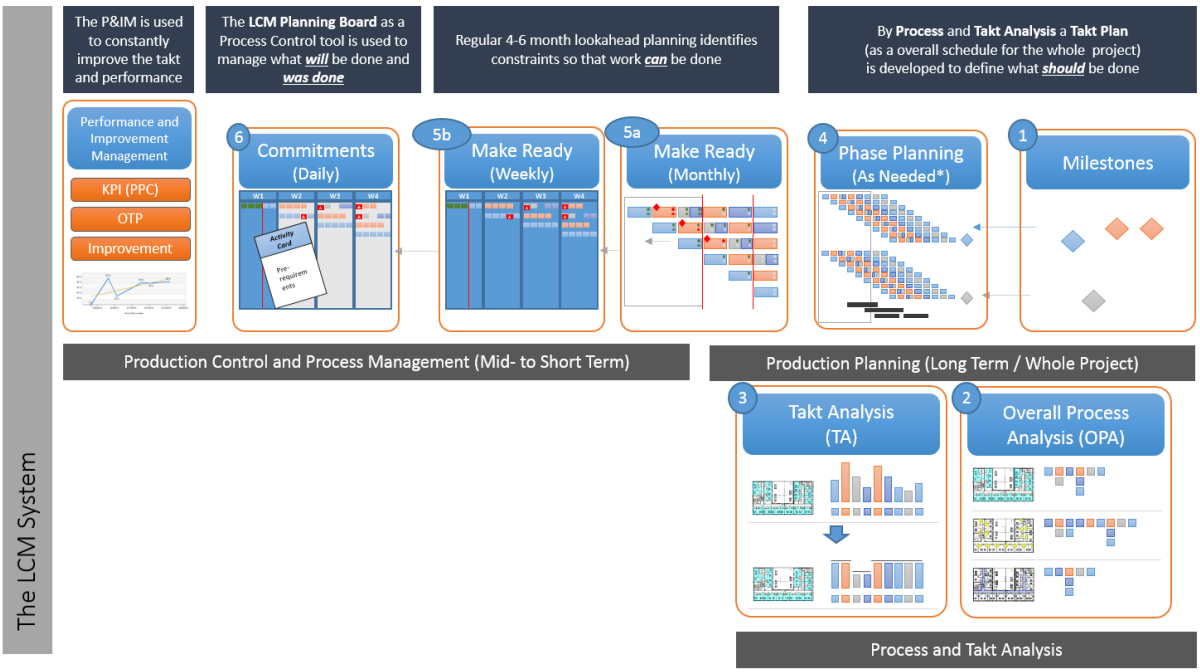

Figure 3: LCM Process (modified so as to use terms from the LPS)

It is important to note that zone types will unlikely be the same for all phases. For example, zone types for rough-in may be different in size and location from those for finishes and those for commissioning. Performing the OPA early (even during the design phases) can identify additional opportunities to reduce the overall duration of projects.

Further, the OPA is done by separating the building into areas that have the same process sequence. In an office building, examples of such areas are: offices, restrooms, kitchens, stairs and elevators, technical rooms, meeting areas, etc.

The process sequence for a zone type is defined collaboratively with the team and typically using sticky notes. Every process step in the zone type is recorded and put into order (in sequence or in parallel). For fast-track projects and IPD projects where there is significant overlap between design and construction, this process should be done early and during design as it should involve the design teams.

Figure 4 shows a team developing the zone types. Figure 5 shows them developing a logical ordering of process steps to be performed sequentially or in parallel with others.

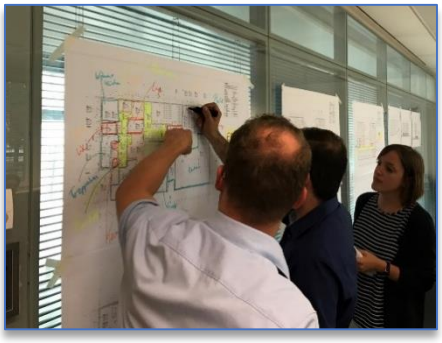

Figure 4: Definition of Zone Types

Figure 5: Processes within Zone Types

Step 1 results in the following information (Figure 6):

- Zone types
- Process steps and step ordering for each zone type

Figure 6: Result of OPA

2) **Takt Analysis (TA)** (*One time)

The Takt Analysis is based on the OPA results. During this step, the team considers the amount of work and the appropriate takt time for the sequence per zone type.

The team then uses the information from the OPA to define the total amount of time to complete the sequence of work in each zone type. Zone types can be clustered into different sizes if similar zone types in the building are different. This is done because a zone type in a building (e.g., a kitchen) will probably have the same process steps (defended in the OPA) but require different amounts of work because they have different sizes. Therefore the takt analysis is used to create the right takt for the specific amount of work in this area.

The result of this step is what is known as the takt "train" for the zone type. The takt train identifies all the work the trades will perform in succession in accordance to the takt time throughout the zone. Accordingly, all trades will proceed in at a constant flow rate, that is, at the same speed. To achieve flow, iteration and analysis are needed to find the right takt time and crew performance / crew size.

Step 2 results in the following information:

- Zone type and amount of work in this area
- Bill of Quantity (BoQ) – material and resources per process step
- Team performance and team capacity

- Definition of the takt time (Figure 7)
- Crew size (Figure 8)
- Duration (Figure 9)

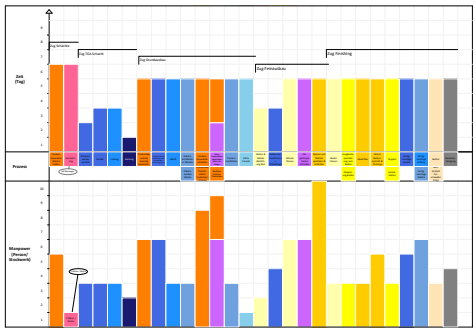

Figure 7: Definition Takted Standard Schedule

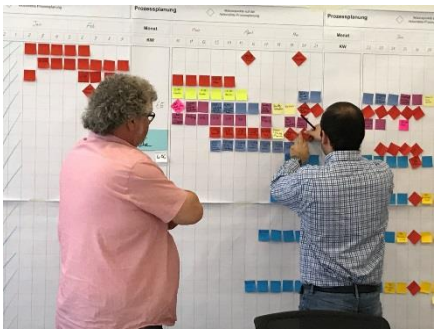

Figure 8: Analysis of Process, Time and Manpower

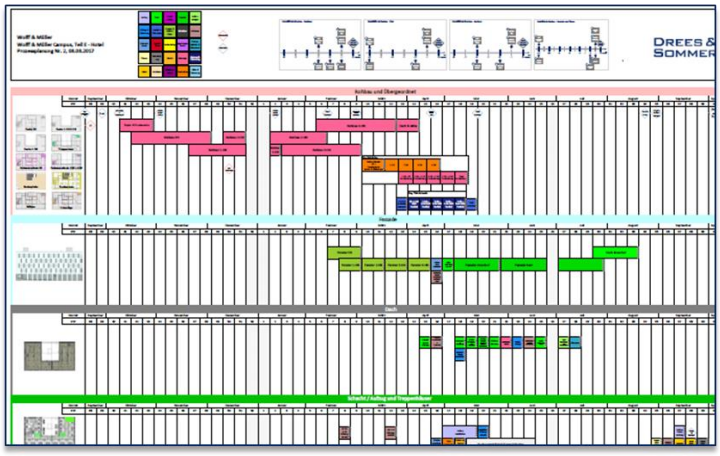

Figure 9: Takted Process Sequence per Zone Type and Takt Area

3) **Applying Takt Planning to Organize the Phase Schedules** (*One time or recurring)

This is the step where the pieces come together to develop the takted phase schedule and production planning strategy for the project. Together, the team defines how the takt train will be moving through the building, how many takt zones will be handled at the same time, and what dependencies between the zones have to be handled. The takt zones, i.e., specifically-defined zone types in a geometrically bounded area of the site, are likely to vary between the different phases of a construction project (e.g., structural phase, interior fit-out phase, and commissioning and handover phase).

Divergent takt times (e.g., 2 weeks in a takt of 1 week, or ½ week in a takt of 1 week) can be handled by using additional crews for a given trade or by rotating crews between takt trains. The goal is to have a leveled flow.

Using takt, the idea is that the trades on the team within a takt train have well-defined work and, because of the repetition, they will likely to be able to speed up their work. This acceleration can lead to a reduction of crew size or a shortening of the takt over the duration of the project.

Step 3 results in the following information (Figure 10):

- Direction of flow though the site
- Number of parallel takt trains and maximum crew sizes

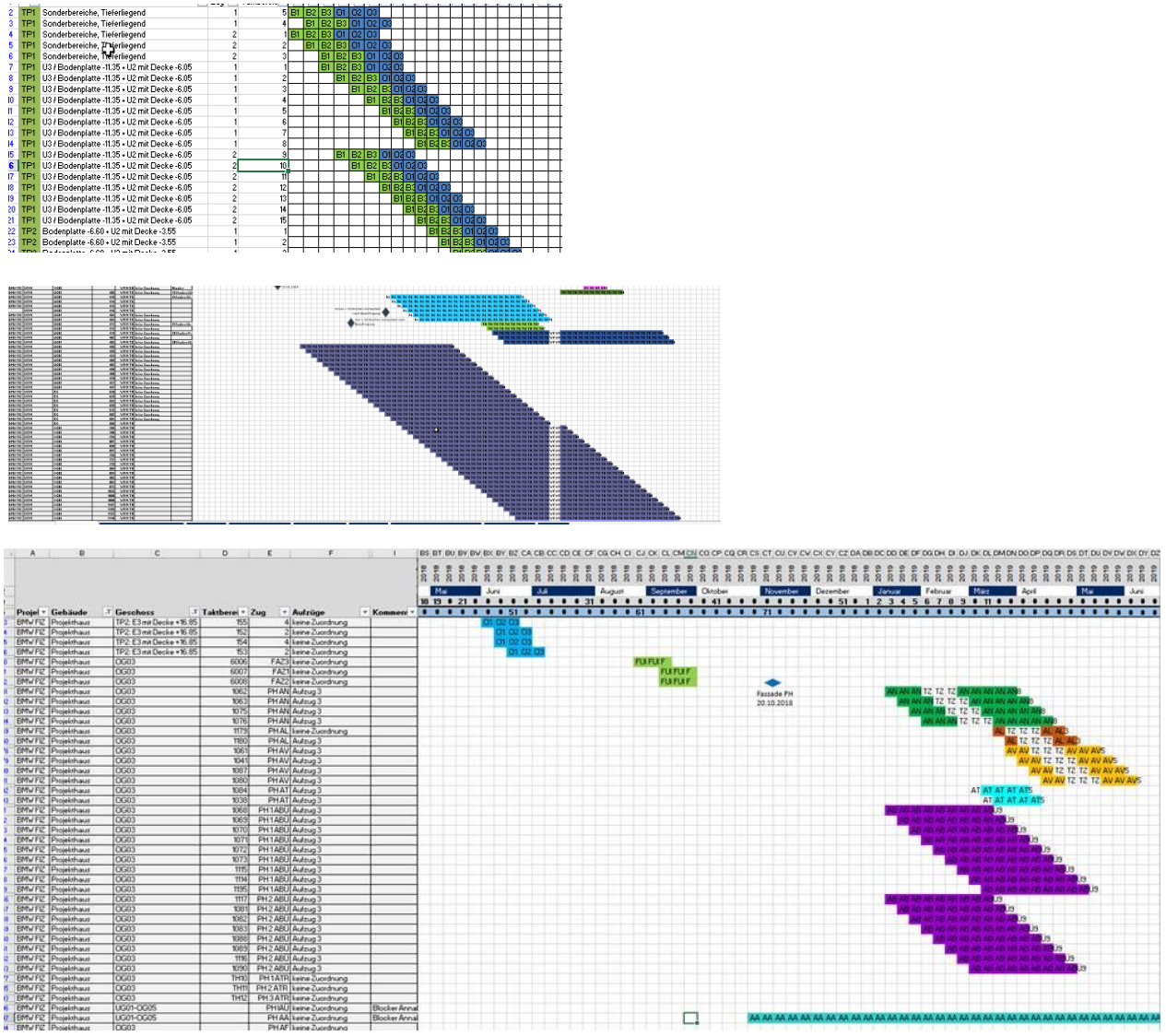

Figure 10: Takted Production Plan for a Complex Office Building

4) **Make Ready Planning:** When using takt planning to organize phase schedule activities, the result is a more predictable process. The team may consider using a longer duration for its lookahead time window, affording more time to make work ready. We recommend

performing make ready planning in two steps identified by the duration of the lookahead horizon.

a. **Make Ready Planning (Lookahead: 4-6 months. Frequency: every 2-4 weeks):** The phase schedule activities are reviewed and linked with all relevant processes including detailed design, fabrication, pre-assembly, logistics, and material delivery. Performing this on a regular basis, e.g., on a recurring schedule once every 2-4 weeks, results in more reliable plans and can help to organize the supply chain and focus on the items that are most important to the site. The focus is on constraints identification, bottleneck identification, and identification of any required quality checks or inspections in the process to ensure a reliable execution free of knowable constraints.

Step 4 results in the following information (Figures 11 and 12):

- Stability criteria
- Information flow
- Overall One Time Performance (OTP) and Process Planning Stability (PPS)
- Action list

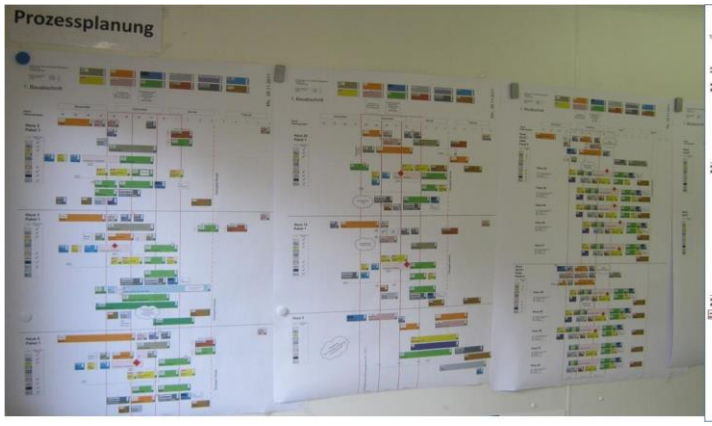

Figure 11: Process Planning

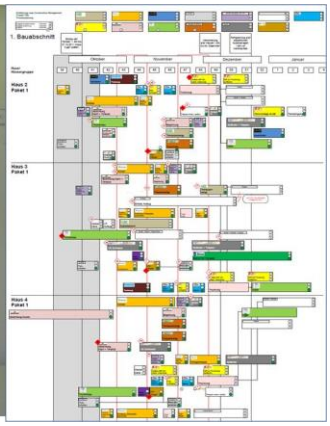

Figure 12: Process Plan

b. Make Ready Planning (Lookahead: 4 weeks. Frequency: weekly)

The visual planning board is the main element of the LCM System production management on-site: it is a visual management tool for daily planning and control of the construction, preassembly work, and logistics on-site. Based on the sequencing, takt time, and the process planning, the daily work is planned on-site for the predefined working areas to ensure continuous work flow. In daily meetings, the foremen and trades adapt the plan to daily needs to ensure a stable planning base with an optimized use of all resources.

5) **Commitment Management** (Daily)

The goal of the previous steps is to "pull" work to the construction site with a predictable information flow and a stabilized production process. The transparency created by the system with key performance indicators (time, quality, logistics, etc.), visual area displays, and to-do lists helps the workers and foremen on-site to optimize the "shop floor" production process.

During the commitment step, everyone focuses on the work for the current week. Commitments are identified and tracked during daily meetings, reflecting what trades plan in the morning and what they complete by the evening. The "stability" of daily promises is then computed as a daily OTP and shown on the planning board. Daily OTPs are also aggregated into an overall OTP indicator.

Step 5 results in the following information (Figures 13 and 14):

- Forman daily work packages
- Daily OTP
- Status of pre-requirement
- Daily check of status, quality and safety
- Daily obstacles
- Action list

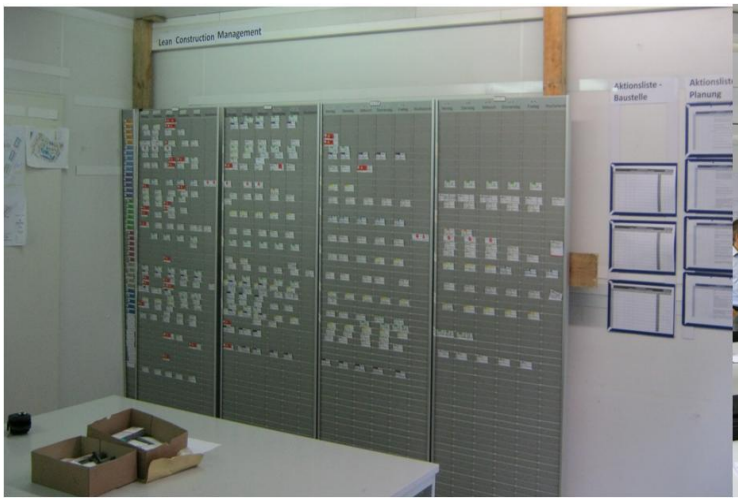

Figure 13: Room with Detailed Planning Board (showing 4-week Lookahead), Daily Floor Plans, OTP, and Action List

Figure 14: Improvement Table

Representing and Managing Takt Plans Using vPlanner

Alternatively, purpose-built tools such as vPlanner (www.myvplanner.com)(Figure 15) can be used to manage the takt plans and integrate the detailed planning boards, the constraints, and the overall phase schedule to create constraint free work for execution.

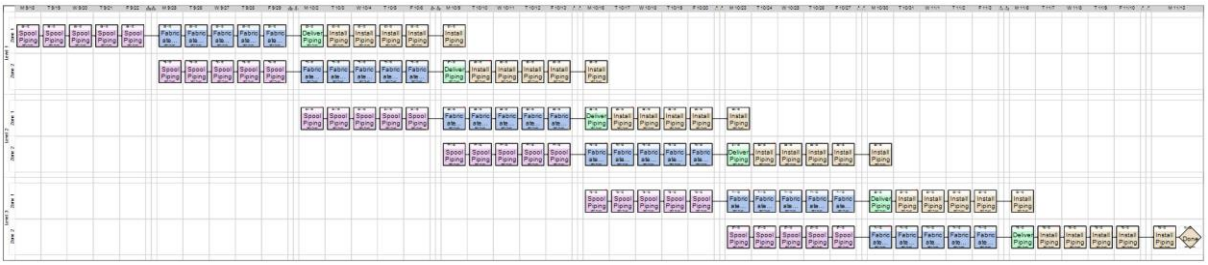

Figure 15: vPlanner Representation of a Takt Plan

Summary and Conclusions

We prepared this handout to help structure the Workshop on Takt Planning held at UC Berkeley on September 26-27, 2017. This handout lays out the steps for takt planning followed in a hands-on exercise led by Drees & Sommer. It also broaches our more general thinking on how takt planning methods may be used on different project types and in different project contexts.

The use of takt in construction planning is relatively new. We look forward to hearing your thoughts on its use on your projects and to researching methods for practical use.

References

References marked with a * are provided in an accompanying handout.

Dunnebier, D., Cleary, J., Galvez, M., Mizell, C., Mueller, K., Pease, J., Tommelein, I.D. (presenters ordered alphabetically) (2014). "An Experiment in Takt Time." Presented at the *16th Annual Congress of the Lean Construction Institute*, San Francisco, CA, 7-10 October, https://www.leanconstruction.org/media/docs/congress/2014/H5B_LCI2014%20Presentation%20Draft_Takt%20Time.pdf

* Emdanat, S., Linnik, M., and Christian, D. (2016) "A Framework for Integrating Takt Planning, Last Planner System and Labor Tracking." *Proceedings of the 24th Annual Conference of the International Group for Lean Construction (IGLC 24)*, Boston, MA, pp. 53-62.

* Frandson, A.G., Seppänen, O., and Tommelein, I. (2015). "Comparison Between Location Based Management and Takt Time Planning." *Proceedings of the 23rd Annual Conference of the International Group for Lean Construction (IGLC 23)*, 28-31 July, Perth, Australia, pp. 3-12.

Harris, R.B. and Ioannou, P.G. (1998). "Scheduling Projects with Repeating Activities," *J. Constr. Engrg. and Mgmt.*, ASCE, 124 (4) 269-278.

Heinonen, A. and Seppänen, O. (2016). "Takt Time Planning: Lessons for Construction Industry from a Cruise Ship Cabin Refurbishment Case Study." *Proceedings of the 24th Annual Conference of the International Group for Lean Construction (IGLC 24)*, Boston, MA, July.

* Linnik, M., Berghede, K., and Ballard, G. (2013). "An Experiment in Takt Time Planning Applied to Non-Repetitive Work." In: Formoso, C.T. and Tzortzopoulos, P. (eds.). *Proceedings 21st Annual Conference of the International Group for Lean Construction (IGLC 21)*, Fortaleza, Brazil, 31-2 August. pp. 609-618.

Lumsden, P. (1968). *The Line-of-Balance Method.* Pergamon Press Ltd., 71 pp.

* Tommelein, I.D. (2017). "Collaborative Takt Time Planning of Non-Repetitive Work." In: Walsh, K., Sacks, R., and Brilakis, I. (eds). *LC3 2017 Volume II – Proceedings of the 25th Annual Conference of the International Group for Lean Construction (IGLC 25)*, Heraklion, Greece, pp. 745-752, www.youtube.com/watch?v=500y23NrNms, doi.org/10.24928/2017/0271