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TAKT PLANNING: AN ENABLER FOR LEAN CONSTRUCTION

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ABSTRACT

Takt planning is being lauded as a new tool for construction planning. It is described in the academic literature and successfully applied in practice. But is it just a tool for planning? This paper aims to show that takt planning can serve as the basis of a framework that supports the application of various lean tools and methods and, accordingly, is a tool to enable lean thinking in construction. Using this framework, the paper illustrates through examples how a project team benefited from using takt to identify where to apply lean tools and methods. It shows how takt informs when and where in the workflow it is appropriate to apply various lean tools and methods such as identification of bottlenecks, workflow reliability (process stability), underloading, process capability, mistakeproofing, standardization, continuous improvement, and cycle time reduction. The contribution of this paper is to highlight that a lean journey that starts with takt may proceed with implementing numerous lean tools and methods other than those directly pertaining to takt itself.

KEYWORDS

Lean construction, takt planning, continuous improvement, project production system design

INTRODUCTION

While takt planning is being lauded as a new tool for construction planning, the benefits of pacing work done by machines and people to a steady beat have been recognised for some time. The application of takt in the manufacturing industry dates to at least the early 1900s. Around that time in Germany, Hugo Junkers (1859-1935) used takt in airplane manufacturing (Baudin 2012), and in the UK, Frank George Woollard (1883-1957) used takt to create flow production at Morris Motors (Emiliani and Seymour 2011). The historical overview provided by Haghsheno et al. (2016) of the origins of takt that informed the use of takt in construction goes back even further in time. Fast forward to this millennium, and we are now seeing an increase in the number of construction projects around the world that are adopting takt planning and control and are reaping the benefits of doing so (e.g., Court 2009, Frandson et al. 2013, Frandson and Tommelein 2014, Linnik et al. 2013, Haghsheno et al. 2016,

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Binninger et al. 2017, Gardarsson et al. 2019, Tommelein 2017, 2020, Lehtovaara et al. 2020).

This paper situates takt planning at the basis of a framework that supports the application of various lean tools and methods. Besides being a planning method, takt planning is a tool to enable lean thinking in construction. The paper therefore starts by summarizing the conceptual foundations of takt planning and providing formulas with the rationale for computing a takt. It then illustrates the elements of that framework with examples obtained through direct involvement in a project, showing how lean tools and methods can be implemented so that the takt plan will be embraced to its fullest.

METHODOLOGY

A question for anyone wishing to get started with lean construction implementation is: Where to start? One option is to start with weekly work planning; another is to start with pull planning; both are specified in the Last Planner System® (LPS®) (Ballard and Tommelein 2021). While these options focus respectively on creating workflow reliability and defining handoffs between specialists, they do not indicate how the work is to be structured (Ballard and Tommelein 1999, Ballard et al. 2001). Takt planning provides a method for that (see pp. 26-28 in Ballard and Tommelein 2021). By providing a work structure, takt planning offers a means to "lower the water to reveal the rocks," i.e., to put strain on the system in order to identify the next opportunity for improvement (Ballard 2009).

Our development of a framework for lean implementation based on the concept of takt started when the opportunity presented itself on a project where the second author was implementing takt planning. The second author and a UC Berkeley graduate student were embedded in the project. They were able to make first-hand observations while also having the opportunity to make interventions affecting the project's unfolding (i.e., action research). Examples from this project are presented in the second half of this paper. They highlight how the takt plan served as the target condition—the strain put on the system—and achieving it would require the use of lean tools and methods to (1) manage negotiations needed upfront to streamline the work and (2) address logistics challenges (e.g., materials, laydown space, lifting) during execution.

The 2016 Benchmark of the Last Planner System® (LPS) (Ballard and Tommelein 2016) barely mentioned takt planning. Since then, takt planning has evolved in the construction industry. The 2020 Benchmark (Ballard and Tommelein 2021) now includes a significant description of takt planning as a work structuring method in the LPS. In this paper, we further expand on the use of takt as a tool to enable lean thinking, i.e., to necessitate the systematic use of many interrelated lean tools and methods. The paper first presents the framework for takt analysis including the takt calculation and planning methodology, and then presents examples from the project to illustrate the use of the framework.

MATHEMATICAL UNDERPINNING OF TAKT PLANNING

This section summarizes the mathematical underpinnings of takt planning and the levers it provides to balance workloads and create workflow.

Takt Calculation

Takt (or 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) (Hopp and Spearman 2011). In manufacturing settings, takt is calculated as follows:

Takt = (Available production time) / (Customer demand) (Equation 1)

Takt applies to high-volume manufacturing, where it may be measured in seconds or minutes, or to low-volume high-variety (LVHV) manufacturing, measured perhaps more typically in hours or days (Ricondo Iriondo et al. 2016). Takt likewise applies to construction. Construction is a kind of LVHV manufacturing specifically structured based on fixed-layout assembly (as some manufacturing systems are, too), which means that workers, equipment, and materials “flow” to complete work in fixed locations, supported by information flows based on decisions made during design and pertaining to the supply chain.

While takt used in construction planning is evolving through on-site experimentation, theory, and support-tool development, it is worthwhile to recognize its mathematical underpinnings. Takt requires a calculation that sets the rate at which a production system should produce to meet customer demand. Demand can be external (the overall customer demand) or internal to the system where each assembly line (in manufacturing) or phase of work (in a construction project) must be paced per the production rate of the previous and the next line or phase so that in combination they will meet overall customer demand.

In construction, demand refers to the project as a single product completed within a given duration. Workers complete work in phases defined with clear handoffs and standard steps for each phase at specific locations (so-called zones). These zones are inherently 2- or 3-dimensional in nature and can be decided on using one of several approaches.

Approaches for Zoning

When takting a construction project, the project work space must be divided into zones to allow for concurrency of work and improve crew management at the job site. However, the underlying assumptions for how to define zones and how to determine the takt are not well articulated (Singh et al. 2020). Several approaches for zoning a project appear to be in use.

One planning approach is to start top-down by defining a location breakdown structure (LBS) for a project phase or the entire project, assessing work in each location, and then choosing means and methods while sizing crews. This is the approach taken in location-based methods such as the Line of Balance, Repetitive Scheduling Method (RSM) (Harris and Ioannou 1998), or Location-Based Management System (LBMS) (Kenley and Seppänen 2009), in which case the objectives are to work in sequence, eliminate crew overlaps, and keep the crew size constant while striving for high resource utilization and buffering with time. When an a-priori defined LBS is used to produce a takt plan, the crew size must be adjusted to synchronize better with the work of successive trades. A shortcoming of this approach is that changing the crew size is only one of several levers available to meet takt planning objective (e.g., keeping the time any crew spends in any location constant while striving to complete all work to meet demand and buffering with capacity to ensure reliable workflow). By revisiting the LBS and iterating, the Line of Balance approach can then possibly result in a satisfactory takt plan, but this raises the questions: Is starting from a-priori defined LBS the best way to create a satisfactory takt plan? What other approaches exist?

A second approach is to start by identifying Standard Space Units (SSU), such as a hotel room, bathroom, or office, then identify the work contents by trade for each one, multiply it with production rates to find the time each trade needs by SSU, and then adjusting resources to find an acceptable upper-bound on the duration each trade will be allowed to complete their work in each SSU (Dlouhy et al. 2016).

A third approach may be labeled "block planning." It starts by choosing a certain duration between handoffs (e.g., a takt 'wagon' that is 5 workdays long) and dividing the site into zones, thus creating time-space blocks. Then comes deciding what work can be done by which trades by zone in the chosen duration, possibly resulting in multiple trades ending up in the same wagon. The Pentagon Renovation project followed this approach (Horman et al. 2003). Court (2009 p. 54) specifically choose a 5-day block (takt) and called it week-beat scheduling. In this approach, the scope of work and crewing is tailored to the time-space block that is locked in for all. Trades therefore may have to crew up and down to stay on schedule. The penalty for changing crew sizes is offset presumably by benefits of the discipline imposed on everyone following the week-beat and can be acceptable especially on fast-paced projects.

A fourth approach uses the Work Density Method (WDM) (Tommelein 2017). This method is based on identifying the work steps trades must complete in a phase (or process) and on mapping the time each crew needs to a relatively fine grid of cells superimposed over the work space. This identification may also be done by means of color-ups, e.g., a single-day color-up would identify the amount of work the minimum crew can produce in a single day. These cells of so-called work density are then combined to zone the work space. Using mathematical optimization for so-called Workload Leveling and Zoning to find the lowest workload possible (Jabbari et al. 2020) and manual adjustment (Singh et al. 2020), the zones can be right-sized to match crew capabilities, means, and methods.

These four methods differ in what they consider to be given at the outset, what objectives are pursued, and how changes are made while iterating to optimize the plan. For example, the WDM and the single-day color-ups differ from the other methods in the sense that they do not start with a LBS or a-priori assumed zones. We next expand on the takt calculation.

Takt Calculation for a Construction Phase

Construction takt is the fixed amount of time a trade gets to complete their work for a given step (a certain scope of their work) in a given zone, with several steps making up a process so that all the process steps in all applicable zones are completed within the required phase- or project duration. In practice, and due to the considerable variation between work phases, construction takt is the result of the analysis done at the phase level. It is rarely calculated at the project level. Each phase may be paced to a different takt. A phase identifies groupings of construction activities of similar nature, such as underground work, structure, overhead systems, in-wall systems, finishes, or testing. Clear handoffs (e.g., third-party inspections) separate one phase from the next.

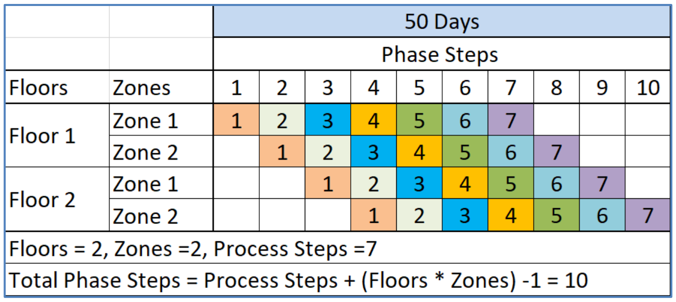
For a given phase duration and number of phase steps, the takt can be calculated:

$$\textit{Construction Phase Takt} = (\textit{Phase Duration}) / (\textit{Total Number of Phase Steps}) \quad \text{(Equation 2)}$$

where,

$$\textit{Total Number of Phase Steps} = \textit{Process Steps} + (\textit{Number of Floors} * \textit{Number of Zones}) - 1 \quad \text{(Equation 3)}$$

The following example illustrates this calculation. Assume that a phase of work for a two-story building must be completed in 50 days. Takt plan development starts by mapping the number of steps that must be performed in succession to complete all work in the phase (i.e., the “Total Number of Phase Steps” in Equation 2). The subsequent analysis is context-dependent. It starts by identifying which work steps must be performed in succession and which can be done in parallel. This reveals the critical handoffs between the steps. During analysis, some steps may be combined while others are split. Figure 1 illustrates the takt calculation where work comprising process steps 1 through 7 is done on two floors, each divided into two zones.



		50 Days									
		Phase Steps									
Floors	Zones	1	2	3	4	5	6	7	8	9	10
Floor 1	Zone 1	1	2	3	4	5	6	7			
	Zone 2		1	2	3	4	5	6	7		
Floor 2	Zone 1			1	2	3	4	5	6	7	
	Zone 2				1	2	3	4	5	6	7
Floors = 2, Zones =2, Process Steps =7											
Total Phase Steps = Process Steps + (Floors * Zones) -1 = 10											

Figure 1: Total Phase Steps Calculation Assuming two Floors each with two Zones

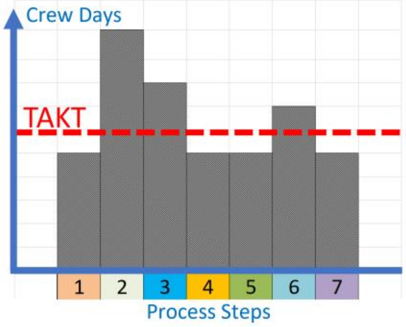


Figure 2: Charting the Process Steps and Cycle Time (expressed in Crew Days) per Floor with the Takt Target (shown by Dashed Line)

The analysis is iterative and produces several takt targets based on the assumed number of zones, for example:

Option 1: 2 Zones: Takt = 50 / (7 + (2*2) – 1) = 5 days / step
Option 2: 3 Zones: Takt = 50 / (7 + (2*3) – 1) = 4.16 days / step

Takt Analysis

The takt calculation sets the production target for each step in the production system, but it does nothing to align the work in each step with the target, and it does not define the location or the size of the zones. The next step is to collect data to determine the amount of time it takes for a crew to perform the work for each process step which is needed to define the crew size, location, and size of the zones so that each trade can perform the work in each step in roughly the same amount of time. The data needs to be collected in a way that keeps options open for further analysis, and thus the Work Density Method is preferred.

Input Data Collection

Color-ups (Linnik et al. 2013) and crew production rates are two related methods to collect data without pre-determining the zones. These can be used to identify the area a single crew can complete in a small unit of time (e.g., one day). In this context, a single crew is the minimum number of resources required to perform a work step in a process.

This systematic data collection approach provides two insights for the takt analysis. The first is the maximum duration to perform the work for each step in a work area (e.g., on the floor). The second is how the work is distributed in a work area: e.g., is it distributed evenly, or is it concentrated in specific locations? When the work is distributed evenly, zone definition is straightforward. However, if the work is not distributed evenly, additional approaches may be considered prior to deciding on zones, such as decoupling the process steps to create new work phases for such locations.

Cycle Time

Once data is collected, the takt analysis continues. The objective of the analysis is to define the location and size of the zones and to determine the appropriate number of crews so that the cycle time for the step when performed in a specific zone is less than the calculated takt.

Cycle time is the projected time it takes to complete the work in a step from start to finish based on the production rate of the crew and the quantity of the work. The crew production rate can be observed or obtained from experience when performing similar work. That is, during production, inventories would accumulate when the cycle time is significantly shorter than the takt, and bottlenecks would emerge when the cycle time exceeds the takt.

Continuing with the example, selecting option 2 and rounding it down to 4 days / step as a stretch goal, the calculated takt is 4 days so three zones need to be defined. Rounding down of the computed value helps to shorten the process duration if indeed the stretch goal can be met, which in turn frees up a time buffer that can be use elsewhere in the phase.

FRAMEWORK FOR CONTINUOUS IMPROVEMENT BASED ON TAKT AND USING LEAN PRINCIPLES

Balancing and finetuning the production system is the process by which cycle time is aligned with takt in such a way that allows the crews to have some excess capacity to accommodate variation and to be able to implement process improvements. To this end, many lean tools and methods can be used.

Underloading Principle: Cycle time < Takt Time

When the cycle time significantly exceeds the takt, a clear choice when balancing the production system is to add crews. However, this may not be the most effective choice. Improvements to the internals of a step should always be considered. Especially when the cycle time only slightly exceeds the takt, internal improvement could bring it down below the takt. Alternatively, improvements to the overall sequence may be considered.

The disciplined data collection and analysis process outlined above exposes opportunities to implement targeted improvements to streamline operations through lean thinking. The following sections explore some of those opportunities.

Step Analysis: Step analysis is the detailed study of the internals of a step in the overall process sequence. The analysis should identify value-adding and non-value-adding work. Additionally, step analysis provides context for evaluating alternative ways of performing the work, such as installing sub-assemblies instead of building on-site. Step analysis can further refine the process sequence itself, especially when considering the internals of the preceding and succeeding steps.

Step analysis is performed prior to production to finetune the means and methods used, and to reduce non-valuing adding work. It continues during production to spot further improvements. Before production starts, step analysis is based on experience and the study of the systems being installed. It can also be based on data collected through direct observation using a mock-up or a first-run study. During production, it is performed based on direct observation of the work and can reveal further opportunities for improvement. Lean tools and methods like 5-S analysis, 5-Whys analysis, and time studies can be used to study and improve the internals of a step.

Design Caused Bottlenecks: If step analysis is done early enough in the process, it could identify certain bottlenecks (design bottlenecks) within the sequence that can be resolved only through a design change to simplify or improve the assembly, e.g., through standardization. Such bottlenecks could otherwise choke the plan.

Mistakeproofing: The detailed analysis of the handoffs between the steps identifies steps that can benefit from related built-in-quality measures to (1) reduce variability in the time it takes to perform the step, thereby making the work product of the step more predictable, and (2) reduce the likelihood of making mistakes and passing defects from one step in the production sequence to the next. For example, during modelling, space claim objects (aka. block-outs) are inserted into the models, during coordination, designers agree on assumptions before working in parallel, or during construction, visual management is used to eliminate the chances of making installation errors.

Decision-making: The clarity regarding process flow steps, the handoffs, and the associated zones that takt planning offers lead to improved overall decision-making. Each step in the process flow is supported by a supply-chain flow starting from design to material delivery. Decisions must be made to release each step in that workflow (e.g., Tetik et al. 2019). Takt analysis makes it possible to group related decisions in smaller batches by zone, and batches can be spread over a period of time according to the takt plan. That is, decisions must be made at the rate of the takt. Small batches create an opportunity to learn and improve the decision when initiating similar phases later.

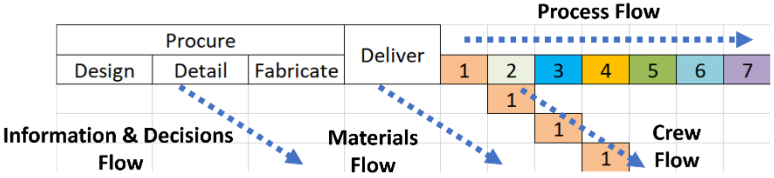
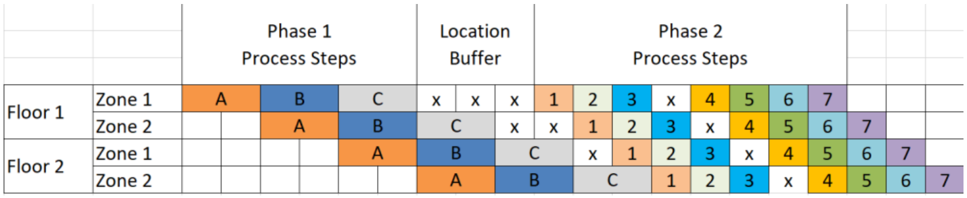


Figure 3: Takt Planning and the Supply Chain

Buffer Management: Buffer management protects the workflow from variability (Dlouhy et al. 2019). Capacity buffers are included in the takt sequence when setting the cycle time for each step to be less than takt. Such underloading gives the crews time to react to variation and complete the work for their step in a specific zone, so they will not delay succeeding crews. Location buffers can be used when steps in the sequence exhibit uncertainty or when the work requires additional space on the floor for materials and equipment. Location buffers can also emerge naturally when a phase of work has a slower or faster takt target than a subsequent phase.



		Phase 1 Process Steps						Location Buffer			Phase 2 Process Steps										
Floor 1	Zone 1	A		B		C		x	x	x	1	2	3	x	4	5	6	7			
	Zone 2			A		B		C		x	x	1	2	3	x	4	5	6	7		
Floor 2	Zone 1					A		B		C		x	1	2	3	x	4	5	6	7	
	Zone 2							A		B		C		1	2	3	x	4	5	6	7

Figure 4: Location Buffers (marked 'x')

Logistics Planning: Takt analysis informs logistics planning. During the analysis and while zones are being identified, teams consider the laydown space required to temporarily house the materials required to install the systems within that zone. Since adjacent zones will be occupied by other work, each zone needs to be defined with enough space to organize the delivery for ease of installation. Kitting strategies should be considered so that deliveries are sequenced to enable just-in-time installation and first-delivered first-installed.

Furthermore, when planning vertical construction, the takt plan makes it possible to identify which steps will start at the same time vertically through the building along with their material delivery requirements. This allows the team to calculate lifting capacity and resolve any bottlenecks ahead of time.

Standard Work: The execution of takt plans allocates resources to perform similar work across all applicable zones. This makes the installation of future work more predictable, and the crews will become more efficient over time as they move from one area to the next. Crews can spot variation and implement countermeasures to control it.

Make Ready Improvements: Make ready planning is the process of identifying and removing any constraints on the work that should be done, so that it can be "done done" (Ballard and Tommelein 2021). Takt planning gives structure to the make ready process and enables teams to look ahead further in the future more reliably. Make ready planning can be done in smaller batches per zone, and as constraints, especially those related to information flow and decisions, are removed when installing the first few zones, they are also removed from later zones for similar work. This reduces variation as more work is put in place and allows the team to look ahead further with more reliability.

The following section provides examples of how the framework was implemented on an actual project to develop execution strategies and how takt helped the project team identify where to implement lean principles to streamline the workflow.

EXAMPLES FROM PRACTICE

Some of the concepts presented earlier were applied to implement targeted lean improvements on a recently completed project, a multi-story Medical Office Building (MOB). Takt planning was introduced at the start of the interiors phase after a late design change switched the interior wall construction from the standard drywall system to a high-end modular factory-fabricated system that included framing, in-wall systems, and finishes. The rough-in phase of the wall construction produced pre-assembled panels of the framing and any in-wall systems such as plumbing, electrical systems, backing, and low voltage systems. The finishes phase of the wall construction produced the final finish panels installed after rough-in was installed, connected, and tested. All the system parts were packed and delivered as a kit of parts for on-site assembly.

The takt analysis was driven by the owner's and the team's desire to improve crew flow during construction, reduce rework, improve decision making, and predict a reliable completion date. The interiors construction scope was divided into several work phases, including high overhead, low overhead, wall construction, finishes, and commissioning.

The takt analysis helped improve the understanding of the requirements for installing the new system and assess the feasibility of implementing the necessary design changes to accommodate the requirements of the new system. Further, the interiors construction team (one GC) was monitoring the process of the exterior construction (work performed by another GC). They were concerned about slipping milestones in the exterior construction schedule impacting the interiors team's ability to complete their work. The goal was to explore execution strategies that would make it possible to identify the last responsible moment for resolving key constraints that could affect releases for fabrication.

During process analysis, the team identified phase steps to be done in succession or in parallel. Parallel steps that required fewer crew members were combined. The trades collaborated to decide which resource-intensive steps should be done in succession. The analysis of the overhead systems suggested that the installation sequence could be simplified if certain systems were split into what the team identified as the pre-overhead phase, to include cores, penetrations, and vertical work that was localized near the shafts and electrical rooms. Data was collected using single-day color-ups.

The takt analysis produced execution strategies that were then discussed for feasibility. These strategies identified the takt targets per phase, the number of zones per phase, the crew requirements, and the known constraints, both external from the core and shell team to release the on-site work and internal to release the detailed design to start fabrication. The team analyzed the tradeoffs between speeding up fabrication to reduce resources at the site vs. speeding up installation to allow for more time to make decisions that would later impact operations in the MOB.

During analysis, several bottlenecks were identified. These were resolved prior to installation by applying lean thinking.

Kitting Strategies Bottleneck: The takt analysis divided the interior floor into six zones sized so that the crews could install the panels in each zone within four days (4-day takt). As the trades studied their sequence of work in detail to confirm the cycle time and validated their thinking through a first run study on a mock-up, they reported needing more time and more laydown space than what had been assumed in the analysis. A root cause analysis revealed that the kitting strategy from the factory to the site required the on-site crews to open all the delivery boxes for the zone and sort the panels to identify which panels are installed in which rooms, that is: supply was not matched with demand. The factory production lines were optimized to group the fabrication of similar panels regardless of their location, and the panels were packaged to maximize the number of panels on the truck. This was most efficient for fabrication and delivery but ended up being out-of-sequence for the site, making it cumbersome for the installation trades to stay within the takt.

The trades and the factory were then challenged to revise the process by improving the alignment between the deliveries and the installation sequence. The factory identified the smallest batch size they could fabricate without losing efficiency, which turned out to be about one fourth of the zone of the takt plan. The trades took that information and sub-divided each takt zone into four work areas. The sequence of installing the work areas within a takt zone was communicated to the factory to match. The modified kitting strategy enabled the trades to realign their installation time to the takt target without increasing fabrication and delivery costs and solved a bottleneck that would have gone undetected otherwise.

Lifting Capacity Bottleneck: All material deliveries made use of a single hoist. The use of a single hoist had been decided at the start of construction and before the takt analysis. When the team considered the number of deliveries for all process steps on a given day across all the zones, they realized that the hoist lifting capacity presented another bottleneck. The trades negotiated hoist time, and some deliveries had to be scheduled at night to match the required speed of installation. Additionally, the GC produced a detailed site logistics plan for truck movements to maximize the utilization of an alleyway which was the only access point for deliveries, which was another bottleneck.

Model Coordination Bottlenecks: Looking further upstream, 3D model coordination was another bottleneck. Initially, the GC had planned for a single model sign-off per floor to release model data to fabrication and planned their resources accordingly. However, the takt analysis required the release of overhead systems for fabrication at different times and in smaller batches than the in-wall systems. Vertical penetrations had to be finalized so that the in-wall panel fabrication could proceed. Process maps for releasing the various systems to fabrication were developed and discussed with the detailers and the design team on a zone-by-zone basis. The analysis revealed code issues to be resolved before starting detailed coordination. The team added modeling resources, increased the frequency of coordination check-ins, and adjusted their model sign-off process so that sign-offs aligned with the zones rather than with the entire floor.

Owner's Decisions Bottlenecks: The takt analysis revealed the last responsible moment for key decisions that the owner stakeholders had to make to release detailed design and coordination to start fabrication in time to maintain the takt target. The advantage when using takt is that decisions can be spread over time and batched at the rate of production. Batching the decisions enabled the owner's stakeholders to prioritize their resources and improve the quality of their decisions.

Bottlenecks During Installation: The project team implemented the LPS make ready planning and commitment management to manage work execution. As the finishes phase deliveries began to arrive at the job site, the team noticed a new, anticipatedbottleneck. The finished panels were delivered by work area similar in size to the work areas previously identified for the panels (one fourth of the zone for the takt). However, the number of finish panels to install was much larger than the number of wall rough-in panels. Each wall panel housed four or five finish panels which resulted in longer sorting times at the job site to identify where the finish panels should go and in which sequence. This on-site sorting required a large, conditioned space. The team used an underground parking level and conducted time studies to improve the sorting task to mitigate the impact on the cycle time.

These are just a few examples of how takt analysis can enable lean thinking on projects. The analysis identified several bottlenecks before the work started and enabled the team to resolve them early through lean thinking. Similarly, during execution, additional bottlenecks were discovered and mitigated through lean thinking as they presented unplanned variation.

CONCLUSIONS

In summary, takt may be viewed as foundational to a framework that supports continuous improvement efforts. Thanks to the clarity a takt plan provides, teams can identify and resolve bottlenecks before starting work, spot and react to variation in the workflow during plan execution, and implement countermeasures. When takt is implemented as a method integral to the LPS, it streamlines the implementation of the LPS. We recommend that teams interested in implementing LPS on their projects start by designing their production system using takt, and then design their LPS implementation to take advantage of all the opportunities production management and control offers. Takt must be considered at the strategic level (takt to inform design and supply chain alignment) as well as at the operational level. Takt planning cannot be done as an afterthought.

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