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Success Factors in the Implementation of Flow Scheduling

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Planning and scheduling are two essential functions leading to the successful management of a construction project. With more complex projects, more sophisticated clients, and shorter timeframes for project development from inception to completion, new scheduling techniques emerge building on the successes and learning from the failures of previous efforts. One of the relatively new scheduling techniques benefiting from lean construction principles and the application of concepts such as Last Planner and Reverse Phase Scheduling is Flow scheduling. Flow scheduling is becoming gradually a mainstream technique in the scheduling of projects with aggressive schedules. It builds on the concept of Takt, Location Based Management System (LBMS), and Pull scheduling where each participating performer looks at the workflow allowing for the activity to start on time when all the required resources are lined up based on discussions and compromises among project team members. Several factors can enhance or impede the successful implementation of Flow. This paper addresses some of these factors and illustrates the successful use of Flow scheduling through a case study.

Key words: Takt, Flow, Lean Scheduling, Success Factors.

Introduction

High competition and shrinking margins of profits, added to increasing project complexity and higher levels of specialty are factors driving the construction industry in a more progressive and collaborative direction. The adoption of Lean Construction principles is becoming mainstream within the domestic and international construction industry. Tools and techniques ranging from reverse phase scheduling (RPS) and the use of Last Planner to the adoption of better supply chain management and collaborative contracting such as Integrated Project Delivery (IPD) are gaining ground among construction professionals and project owners alike. The focus in scheduling has switched from long term planning spanning the whole project duration to shorter term planning covering time windows from six to eight weeks at a time. This change resulted from increasing amounts of uncertainties in the long term, and a closer focus on the throughput of operations leading to productivity and production improvements rather than local optimization of construction activities. This also resulted in a switch from a predominantly "Push" mode of scheduling, where each activity is driven by its predecessor, to a "Pull" model taking the end product into consideration and allowing the activities to be completed at the last responsible moment to ensure meeting project deadlines. This move attempted to adapt concepts and techniques that have a proven success track record in the manufacturing industry to the construction industry. One of these concepts is Takt time, which is defined as "the division of available work time per shift by the customer demand rate per shift" (Rother and Shook, 1998). It is also defined as "the unit of time within which a product must be produced in order to match the rate at which that product is needed" (Frandson et al., 2013). Flow planning is an interactive and collaborative process where Last Planners (usually foremen of different subcontract trades) work together to create a detailed construction schedule. The goal is to generate a workable construction schedule and to validate that the schedule meets the project milestones, while gaining consensus and alignment from all the Last Planners involved. Recent industry delays caused by Covid-19 and the supply-chain disruption necessitate the move from traditional planning to a more agile and resilient approach. Flow can contribute to improving productivity, and can therefore be used as a mitigating factor against future unforeseen disruptions

History and Background

Since its introduction in its more recent form in the late nineties, the concept of lean scheduling has witnessed a wealth of research around the theory and implementation of Lean and Takt planning in construction scheduling. Ballard and Howell (1998) drew the comparison and contrast between the manufacturing industry and the construction industry with respect to the motion of product (object) versus the motion of labor (subject) and concluded that the construction process time and space are interlinked and co-dependent. Dlouhy et al. (2014) identified the concept of establishing Standard Space Units (SSU), which they defined as "a small and independent unit according to structural and manufacturing characteristics to divide the functional area of work into spatial areas that can be finished independent of one another". Seppanen (2014) compared Takt time planning to traditional Location Based Management Systems (LBMS) and concluded that they can be combined resulting in a reduction of the project duration if the project's critical path went through the locations and tasks following Takt time. Daniel et al. (2018) investigated the influence of procurement methods on the successful implementation of lean scheduling using the Last Planner System (LPS) and concluded that a mindset change towards collaboration among different project stakeholders is fundamental to successful LPS implementation. Similarly, Mossman (2014) concluded that LPS can be used with any project delivery system, especially Integrated Project Delivery (IPD) which is based on an initial assumption of trust that is regularly verified. Frandson et al. (2013) identified Takt planning as a "work structuring method, which serves as part of a production system design, and developed an iterative six-step process for its implementation: (1) Data gathering, (2) Zone definition, (3) Trade sequence generation, (4) Individual trade duration, (5) Workflow balancing, and (6) Production schedule finalization". In another publication, Frandson et al. (2015) explored the similarities and differences between Location Based Management Systems (LBMS) and Takt Time Planning (TTP) and concluded that both focus on creating a balanced production schedule with a predictable timing of work while also preventing spatial interference between trades. Their work focused primarily on comparing TTP to the Line of Balance (LOB) technique. One of the major differences is that LOB required identical, or almost identical repetitive steps (e.g., floor plan or footprint), whereas TTP can allow for a variation in that footprint provided that "Balanced Zones" or "Densities" are established. Both techniques support buffers to prevent interference among different trades. These buffers could include (1) time, (2) capacity, (3) space, and (4) workable backlog.

Flow Builds on Takt Planning System

Flow takes into consideration the interaction of the three variables that must be solved for: Areas of work or zones, Takt or tempo, and sequence of work. Zones separate the project work into similarly dense areas, which are not necessarily identical, but require similar balance of crews and intensity of work. Columns, walls, joints, or other distinguishable features can delineate the demarcation lines separating zones. Takt is the rhythm or tempo at which work within the zone will be completed. The most common Takt in construction is a working week, or 5 working days. It can be shorter, allowing for a time buffer to complete any workable backlog. Takt time longer than 5 working days is not desirable as it breaks that tempo, and zones must be reduced accordingly to fit that Takt. The third element is work sequence, which defines the repeatable steps or tasks needed to complete an area or work (e.g., wall studs, MEP rough in, Insulation, hanging drywall). This sequence will be repeated in different zones. The determination of zones and Takt are more of an art than a science and can be perfected through an iterative process. Sequences may be dictated by hard logic (only one-way of doing the work) or a soft logic (a preferred method among many possibilities). It can also be affected by internal or external constraints.

Preparation for Flow Planning

For the successful implementation of Flow planning, several structured steps must be conducted in an orderly fashion. These steps include:

1- Determine the area(s) / Task(s) to be flowed
2- Perform quantity take-offs of the scopes that will be longest to perform (HVAC duct, Electrical, Drywall, etc.). Calculating these quantities will be conducive to negotiating durations with the subs based on the simple formula: Duration = Quantity / Production rate.
3- List all tasks (activities) for the typical zone (area to be flowed)
4- Based on the calculated quantities and the subcontractors' production rates, durations can be calculated determining how long it will take a typical crew to perform each activity across a whole floor.
5- Each floor will be broken into areas or zones of reasonably similar densities (similar durations) to establish the Takt time. Some areas (stairwell, elevator shafts, Mechanical rooms, etc.) may be intentionally left out of the zone calculations as they will have a different Takt and serve as workable backlog.
6- Verify that all the other activities can be performed within the selected Takt.
7- Check for crew balancing which can be achieved iteratively by moving the zone boundaries until such balance is reached

Once these pre-planning steps are achieved, meetings with the key subcontractors are conducted, especially if they are new to the Flow concept, to explain the logic and get their buy-in and commitment. This may result in another review of the Takt and the zones. Color-coded Post-it sheets are used to illustrate the interactions among the key subcontractors and the flow of their work through different work zones. The main two factors to be addressed in this meeting are crew sizes needed to meet the Takt and the proper sequence of work steps. Once the key subcontractors agree to this work plan, the rest of the subs can keep up with the work, as it will need fewer resources. Once the schedule is prepared, it is distributed to all subs for final review and comments. Once revised, it will be approved and posted to all subs.

Success factors for Flow implementation

Many factors can contribute to a smooth and successful implementation of Flow scheduling. Some of these factors are discussed hereunder. Some projects may lend themselves to more or less of these factors.

1- **Project delivery method / Client Buy-in:** Although it has been reported that Flow and Takt planning can be adapted to any project delivery method (Design-Bid-Build, Design-Build, Integrated Project Delivery, etc.) with different types of contracts and payment methods (Firm lump sum, Unit price, Guaranteed Maximum Price, etc.). Nevertheless, more progressive clients who understand lean processes and collaborative contracting are easier to be on-board of Flow planning and scheduling. Clients that are more traditional may resist the idea, as they are used to more conventional top-down methods of planning and scheduling.

2- **Design and construction modularization and preassembly:** Modularization helps with the standardization of the work zones and densities, whereas preassembly can ensure better quality, less rework, and shorter installation time. To maintain lean elements for the project, preassembled units (Bathroom pods, precast elements, etc.) should be delivered on a just in time (JIT) basis to avoid storage needs and double handling on-site.

3- **Team Harmony and Learning Curve**: Building long-term alliances with the key subcontractors results in working with the same group of subs, which helps create more trust among the key performers, thus expediting the learning curve and fostering better communication. New team members can be brought on-board faster, and their buy-in can be achieved easier once they see a couple or more of the performers familiar with the system and trusting its results.

4- **Selection of the trades that can be flowed:** Although, theoretically, any trade can be flowed, most of the recorded success has been with the finishing trades. Some trades lend themselves much easier to flow than others. Structural steel contractors, for example, have a relatively tight schedule, and are used to their own pace and method of work. Reinforced concrete, on the other hand, can be easily broken into zones and smoothly flowed and coordinated with other external enclosure activities.

5- **Zone selection and establishing densities:** As mentioned earlier, this is more art than science. It has a reciprocal role with the selected Takt and the geometrical layout of the work areas, as it affects and is affected by the Takt time. Establishing the correct zones helps with the work balance and crew allocation. Figure 1 displays an example of proper selection of balanced zone densities.

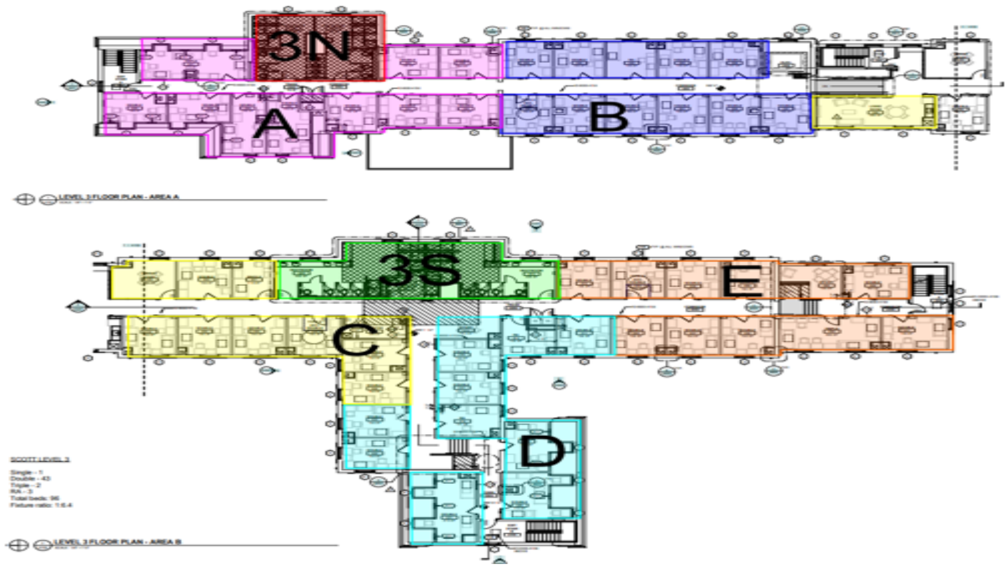

Figure 1. Establishing zones of equivalent densities

6- **Space Availability / Crew Balancing:** Balancing the workload for different trades and crew balancing are important ingredients for any work schedule, and especially so for Flow. Adjusting the crew size may take several attempts until we reach a balance that allows for optimum employment and productivity for the available crews without the need to start/stop/resume work, which may prove hard to recall crews that have been dismissed.

7- **Prototyping / Mockups:** The first of multiple repeated zones or work areas can serve as an in-place mockup to resolve any possible kinks in the process. This works especially well for interior work. Exterior mockups on the other hand may be a bigger challenge due to the external exposure to the elements and the longer lead-time. Figure 2 shows a sample mockup for façade and window details.

Figure 2. Mockup

8- **Standard visual aids:** Standard post-it sheets that are color-coded by trade or discipline provide more familiarity with the process and can lead to better visual inspection of the plan. It also helps the participants see the timing and location of their involvement. These visual aids can also provide both planning and control tables and graphs that enable to participants to observe any deviation from the plan and the need for rebalancing/recalibration. The key, as with any other plan, is regular updating. Figure 3 displays some of the visual aids used on-site with color coding for different responsibilities.
9- **Gemba walks:** This is the way to gather information through observation and interaction with the field performers where value is created. Its main purpose it to observe deviations from the plan and to implement the proper corrective action when needed. Weekly Gemba walks are essential to monitoring and controlling the successful implementation of the plan. It helps get input from the actual performers, thus implementing feasible and actionable change. If the Takt is less than a working week, the Gemba walk schedule needs to be synchronized with the shortened Takt to avoid any backlog and accumulation of errors.
10- **Workable backlog on areas that cannot be easily flowed:** Pulling these areas into the flow is key to the success of the plan. These areas become a "reserve" for moving workers off the flow path and then pulling them back in. It requires special attention from the project manager and can be perfected with time. Examples include mechanical rooms and other congested areas with a heavier worker concentration.

Figure 3. Visual aids for color-coded responsibilities and Weekly Work Plan

11- **Working with, not against, CPM:** Flow scheduling is not a complete substitute for the critical path method (CPM). Both can work together to improve each other. A milestone schedule is prepared in the traditional CPM fashion to get client approval on major project dates and milestones. Flow schedules focus more on the short term, six to eight weeks periods. Upon their completion, flow schedules can be presented in the easily understood Gantt chat format, as this is the easiest and most straightforward mode of schedule communication among different stakeholders. Dedicated flow scheduling software, such as V-Planner, may be used in conjunction with regular CPM scheduling software to coordinate and communicate to the different stakeholders. Figure 4 displays a Phoenix schedule together with a V-Planner schedule for the same activities.

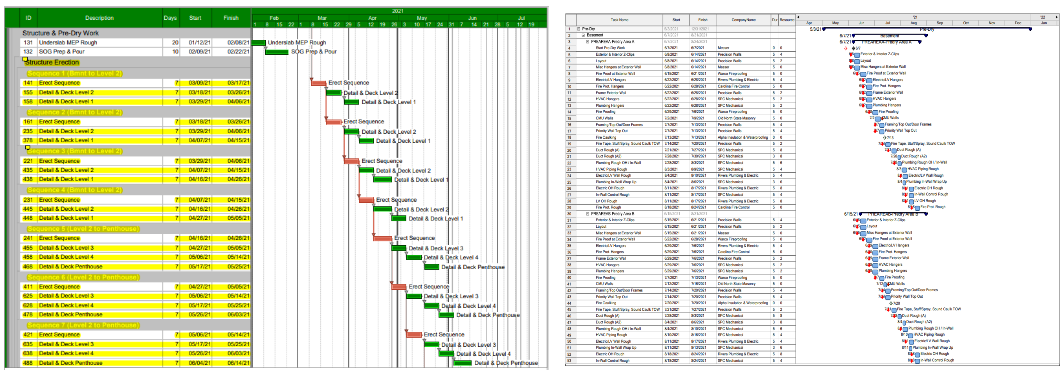

Figure 4. Traditional CPM (left) and V-Planner Flow schedules (Right)

Case Study

A qualitative case study is listed hereunder highlighting the implementation of most of these success factors on a project consisting of two identical high-rise towers in Columbus, Ohio. The Construction Manager @ Risk (CM@R) was a reputable organization based in the Midwest, with an annual volume of work exceeding $1 Billion. The first tower (East Tower) was executed through a crew of contractors and subcontractors following the traditional scheduling and organization approach, whereas the second tower (North Tower) was executed and coordinated using the flow method of planning and scheduling. Some of the comments of the executing team on the East Tower include:

1. Floors were congested with workers. Project continuously struggled with multiple trades on top of each other in each condo unit.
2. Floors were congested with multiple contractor's material.
3. Excess material was left behind on each floor. Subs would order new material rather than see the remaining material that they had on the job to utilize.
4. Missing framing for ceiling lights, access panels, etc. The drywall contractor was always jumping around floors addressing "loose ends".
5. Shaft walls were not done ahead of time. Created "leave out" areas on every floor that forced the drywall hangers and finishers to return and complete.
6. Quality was difficult to manage as the work was spread out and different trades and people were doing the same tasks on multiple floors.

Whereas the comments from the team working on the North Tower included:

1. Easier to deliver product to the site from the shop. Deliver by floors vs half floor, partial floor, etc. Makes the shop much more productive and efficient.
2. There is no room on site to store material, so this was a significant improvement from Parks Edge East.

3. Easy to manage the work since only one subcontractor was in each area at a time.
4. No congestion on floors. Implementation of the 5S became a priority to all the subs.
5. Makes ordering material easier. Can easily see what's left and what is needed on each floor.
6. Establishes clear expectations on crew productivity. The crews can see exactly what they need to get done in each day to meet the takt time.
7. All shaft walls done ahead of production framing a. making Inspections easier to manage
8. Quality Control Plan much more defined and communicated – easier to identify issues with less congestion on the floor/area
9. Better and much more focused approach towards quality.
10. REPETITION – use the same person(s) to do the same tasks with repetition. Less chance for errors.
11. Less overtime, unless the work fell behind. Late work completed through workable backlog.

Figure 5 displays a space comparison between the East Tower (right) versus the North Tower (Left)

Figue 5. Space comparison between East and North Towers

The North tower was completed on schedule and on-budget, with a work force averaging 82 workers. The East tower used twenty percent more resources with an average workforce of 104 workers.

Conclusion

The implementation of Flow in scheduling and executing projects leads to better coordinated activities on site, resulting in higher project efficiencies, and leading to a safer environment to operate. Long term alliances and working with trusted project partners accelerates the learning curve and allows for transfer of the team experience from one project to the other. Several factors can affect the successful implementation of Flow and other principles of lean construction. Flexibility in establishing densities and work zones reduces the magnitude and severity of unexpected disruptions. Increasing project complexity necessitates looking into innovative teaming agreements and buy-in to allow for earlier contractor involvement and valuable input in project planning and execution. Modularization, work packaging, preassembly, and mockups are different proven tools leading to reducing the project team footprint and allowing for better use of available limited space. Not every project or every activity can be flowed: Flow when you can, and use "unflowable" areas as buffers for workable backlog. Contractors who experience flow for the first time and can see its benefits act as ambassadors for the concept and help propagate it to subcontractors on other projects. Following lean processes such as the Gemba walk, 5 S, reverse phase scheduling and simple visual aids can enhance teams' understanding of the concepts and the techniques involved therein. Flow is not a complete replacement for the traditional critical path method, as milestones and stage gates can still be scheduled using traditional CPM software, and translated into Gant Charts for ease of communication, especially with project owners.

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