THE MARRIAGE OF CPM AND LEAN CONSTRUCTION

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ABSTRACT

Critical Path Method (CPM) scheduling is the hallmark of current project management practice. This paper explains how one practitioner applies the Lean ideal of a "custom product, delivered instantly, without waste" to CPM scheduling. The paper also demonstrates how CPM scheduling and the Last Planner™ System can be complimentary processes that improve crew flow and work flow in a Lean based project management approach. Further, the paper introduces the concept of attention as a wasteable project resource and presents methods for its efficient utilization.

KEYWORDS

CPM as product, crew flow mapping, interactive scheduling, soft logic, crew-centric planning, coordinating conversations, attention as resource, pull intensity

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INTRODUCTION

When any of us use the words CPM schedule in speaking about project management our listeners will nod their heads knowingly. We will assume that they and we share a common experience and picture of what a CPM schedule looks like, how it is created and updated and how it is received and utilized in the field. We might throw in the phrases centralized planning and old-fashioned push and again heads will nod and assumptions will be made. The imagined CPM schedule might be a full-scaled Work Breakdown Structure (WBS)-based, resource loaded and leveled ideal or then again it may not. In fact, despite a detailed and widely accepted definition of what constitutes a CPM schedule and rigorous rules for its use, CPM scheduling remains a craft skill with wide variances in methodology and utilization across industries and even within companies based on the past experience of individual schedule practitioners. This variance in the application of scheduling practices provides for enough flexibility to bend the CPM into a system that supports and enhances the Lean Construction process. This paper explores some positive outcomes and common features of CPM schedules used in tandem with the Last Planner™ System.

CPM DEFINED

Let us define what we are talking about when we use the term CPM: If we have created a network that contains a sequence of interdependent activities, each having a scope and a duration and if we are then able to calculate early and late dates by means of a forward and backward pass then we will have created a CPM schedule. The dependencies among activities can be related to the physical erection sequence *(place foundations > erect superstructure)* or to the sequential utilization of shared resource as in a crane or specialized crew *(erect superstructure @ wing A > erect superstructure at wing B).* The former is usually referred to as hard logic and the later as soft logic.

CPM AS PRODUCT

For a moment let's take a step back and look at the CPM schedule as a product delivered over the course of a project and consumed by a changing cast of customers as the project progresses. If we apply the lean ideal to CPM scheduling we define success as the perfect schedule, delivered instantly, without waste. To optimize the CPM process we have to define how it delivers value to the project and seek to avoid non-value adding activities within the planning effort. In doing so we focus on the flow of the schedule through the project planning process and both the demands it makes on the project team and the value it delivers to this same team. The foundational premise of this paper is that the primary function of scheduling and planning is to optimize production by concurrent management of crew flow and work flow. *If scheduling is primarily being utilized for contract claim or claim defense documentation very little of this discussion applies.*

There are multiple triggers for the production of project schedules including contract requirements, company policies, project manager preferences and designer, supplier and subcontractor requests for required delivery or mobilization dates. The goal in creating a lean schedule is to fulfill all of these needs with one document in the shortest time possible using

the minimum number of resources. The trick is to identify who the consumers of the schedule are and discern what their measure of schedule value might be. Let's identify some consumers of scheduling and the value they might be seeking.

CPM CONSUMERS AND VALUE RECEIVED

OWNERS

An owner will typically look at just a few features of the project schedule including the project **start date**, **impacts** to adjacent spaces or processes if a modification or rebuild project, **cash flow** requirements and the project **end date**.

The value received from the schedule is the ability to communicate project duration and financing needs to upstream and downstream interested parties.

DESIGNERS

In a design/build contract environment the designer will be looking at downstream procurement and construction need dates for **engineering deliverables**.

The value received from the schedule is the ability to rank design tasks hierarchically based on construction need dates and to adjust project staffing size to support the needed design workflow.

SUPERINTENDENTS

The project superintendents hopefully will be attending to optimizing **crew flow and workflow** through the project site. Crew flow is analogous to work flow but recognizes construction's unique need to sequentially flow crews through the same space to assemble an unmovable product. Managing crew flow and workflow is the balancing of load and capacity.

The value received from the schedule is stability in crew size and work assignments (capacity and load) and the attendant benefits to crew learning, morale, safety, productivity, etc.

MANAGERS

Managers need to communicate dates and sequencing information across a wide group of contacts throughout the project. In the course of innumerable interviews and **coordinating conversations** the manager uses the schedule to articulate a four dimensional **crew flow map** and report project schedule status as an iterative process.

The value received from the schedule is a one stop recording document for the current coordinated plan that can be shared to upstream and downstream project participants.

SUPPLIERS

Off site providers of detailed design, fabrication and delivery of materials or equipment will use the schedule to coordinate their in-house production activities with the project need.

The value received from the schedule is the ability to provide **just-in-time** delivery of products to the jobsite reserving as much time as is possible for the off site producer to perfect design and optimize in-house production.

SUMMARY OF VALUES

A summary listing of the values received by the consumers of CPM schedules includes project duration, impacts to adjacent facilities, expectations for the timing of engineering deliverables, crew flow map, just-in-time delivery opportunities.

What we purposefully left out of the above listing is the **earned value** piece because our experience has shown that the creation, maintenance and reporting of a schedule used as an earned value data base requires more in resources than it delivers in risk mitigation value. Let us repeat that assertion as it holds a very important place in our beliefs and in this paper's assumptions: CPM schedules driven by scope definition (WBS) and resource loaded for planning and enforcement purposes (Earned Value) do not deliver enough added value to warrant their use. In fact they waste an extremely valuable project resource, that being the attention of the installing superintendents. More on this later in the paper.

CREW-CENTRIC PLANNING

We can deliver on the above list of values with a logic driven schedule focusing on crew flow through the project time and space. With modern project management software we can do this interactively, creating, updating and detailing the CPM in real time. Using a projected image of the active schedule file, project stakeholders negotiate for duration and sequencing concessions while viewing their impact on the overall project plan and downstream trades. Starting with a milestone schedule, we identify the owner's project delivery expectations, highlight some important dates for coordination with adjacent non-project on-going activities and present some hoped for milestones having to do with the mitigation of the effects of weather on the project. We assemble the project stakeholders and build a logical plan in real time with calculated start and finish dates from relationships which detail the flow of work crews through the project space. Tasks are built up not from the WBS, which unnecessarily splits the plan down contract scope lines, but rather with descriptions of the successive utilization of project space by various crews, the crew being the smallest operational unit of producers. As an iterative process, with a changing cast of site production managers as the project progresses, the active schedule file is detailed and updated in an interactive setting that promotes the coordinating conversations so important to project success. The plan is crew centered and focuses on reliable crew flow among previously released workspaces.

SOFT LOGIC

The reduction of the planning discussion to crew flow perks the interest of project superintendents who are the most important insurers of project success as they control all the installing resources (the crews). Crew flow is recorded and reported using soft logic ties among schedule activities. Soft logic ties connect two activities that will be completed by the same crew or that share a common resource such as a large crane. The corollary traditional

hard logic ties record hand-offs between successive crews required by the erection sequence. Figure 1 illustrates the difference between soft and hard logic ties:

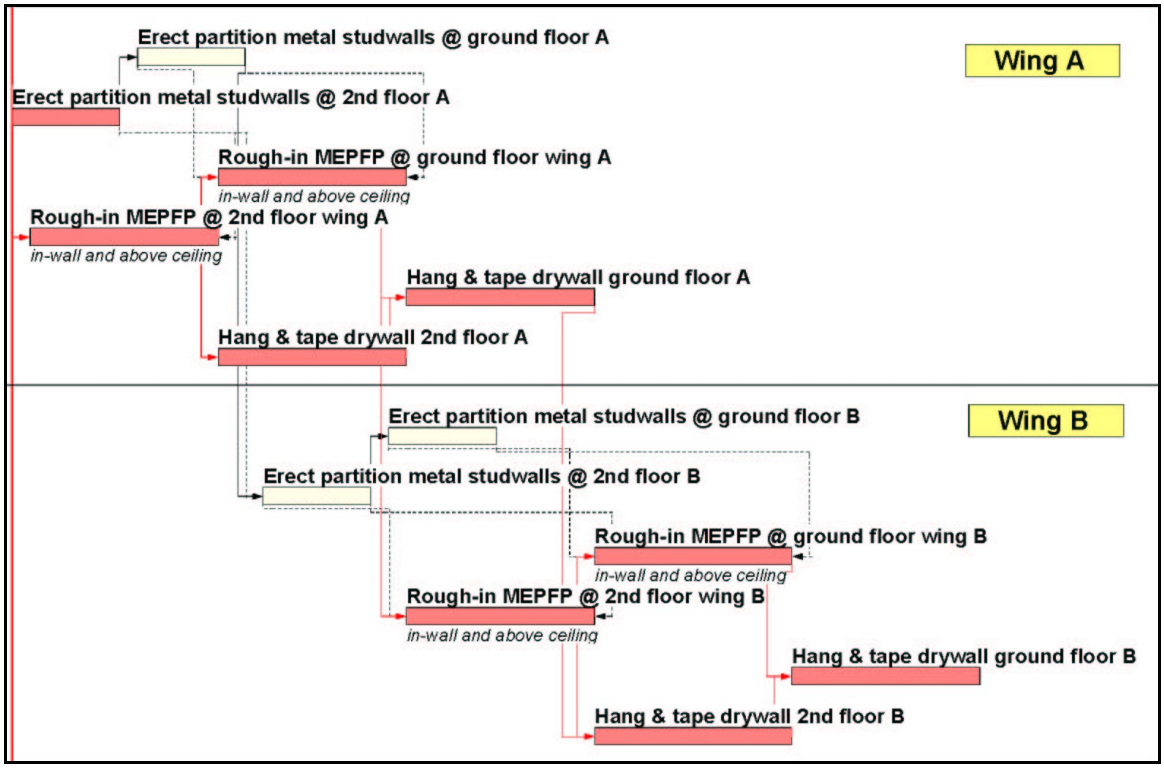

Figure 1: Network fragment showing hard and soft logic ties

In the above network fragment the relationships among activities on the ground floor and 2nd floor and wing A and wing B are soft logic ties illustrating the planned crew flow among the available workspaces. The hard logic ties show the handoff of work from a crew to a following crew in a single project space. Utilizing soft logic, individual trade superintendents can protect site crew size and avoid crew starvation, the condition wherein an optimized crew runs out of productive work. Note the use of the crew designation MEPFP which stands for Mechanical, Electrical, Plumbing and Fire Protection which are lumped together because they all utilize the project space in exactly the same way at exactly the same time. By engaging those who control the project resources in an interactive discussion of the productive flow of their workers through the time and space of the project we can systematically obtain higher quality commitments and therefore better adherence to plan. The project benefits from this crew flow stabilization with higher productivity, better crew learning, improved morale and a safer work environment.

DETAIL IS THE ENEMY OF SCHEDULES

Site managers and superintendents partake in hundreds of coordinating conversations in the course of a week or even a day. In these conversations promises are exchanged regarding the utilization or delivery of resources be they work crews, materials, site access, large

equipment, small tools or project information. Most of these promises have a very short shelf life requiring fulfillment during the day or week in which they are made. The CPM records a series of commitments that cover a much longer duration and taken as a whole, the entire duration of the project.

When determining or testing the project duration using a logic driven CPM schedule it is important to avoid driving too much detail into the planning process. WBS, resource loading and earned value have been presented as either non-value adding or even detrimental planning efforts earlier in this paper. How much detail is too much? You can tell you've got too much detail in the CPM when you will have lost the attention of the superintendents. This speaks to the identification of value in the creation of a lean CPM schedule and can be illustrated by the following rhetorical question: Why might one continue adding details to a schedule after the production controllers have lost interest? Let us introduce attention as a valuable and wasteable project resource.

ATTENTION AS RESOURCE

The explosive growth in the capability and sophistication of computer based project management software over the last few decades has not been closely matched by a parallel interest in or need for the data and analysis that they provide. This is especially true of the interests and needs of the front line production manager on a construction site. The planning effort, as it demands time and energy from the front line managers, has to compete with day-to-day project requirements for safety and environmental considerations, scope management, financial management, labor relations, owner relations, procurement, payroll and documentation. In this competitive environment, the competition being that for the attention of the front line production manager, the CPM schedule must necessarily deliver its value quickly and efficiently or it faces the distinct possibility of loosing out to other persistent demands on the manager's time and attention. Just because we can create an extremely detailed WBS-based resource loaded and leveled schedule and just because we can report its content in a mind-numbing array of diagrams, charts and graphs doesn't mean we should. In fact, practiced as an interactive discussion of crew flow and site coordination needs, with data captured and analyzed for alignment with project needs in real time, the CPM scheduling process can fulfill its assigned functions very efficiently. The test should always be whether the CPM schedule is delivering value and being readily consumed by the site production controllers.

CPM & LEAN TOGETHER

Armed with a collaborative four dimensional crew flow map as suggested above we now bring the Last Planner™ System to bear on the individual crew assignments and coordination required to make the plan happen. Standing alone, the CPM is disinterested in the elbow-to-elbow coordination of the individual crews out on the site. It knows what the crews are doing and where but not how. Again standing alone, the Last Planner™ System is disinterested in the measurable contribution to overall project success caused by the completion of an individual crew assignment. It knows the who, where, and how but not the why. In attempting to operate without the large picture CPM schedule the Last Planner™ System can

be equated to attempting to run Christianity without Hell. There is no quantifiable downside to a lack of performance. A poor Planned Percent Complete (PPC) number for a week might or might not place the project plan in jeopardy; we need the CPM tool and its float calculation to find out.

Current Lean Construction thinking divides work into categories based on the task's readiness for assignment to a crew. Crew assignments are pulled into the weekly work plan by the responsible supervisor's acceptance of an assignment from an available pool of ready tasks. There exists another set of tasks that the master plan suggests must be done but are not as yet ready for assignment to a crew. Typically represented as distinct subsets of the total pool of uncompleted work, an alternative view presents itself using float calculation to measure pull intensity across the project matrix. In this view the individual tasks are ranked using total float so that make ready efforts and weekly crew assignments are brought to bear where they will do the overall project the most good. In this scenario the CPM and the Last Planner™ System inform each other of the pull intensity (total float) and planning reliability (percent planned complete) as the project is planned and re-planned in a periodic cycle as the project progresses. Figure 2 illustrates the planning/re-planning cycle using both CPM and the Last Planner™ System.

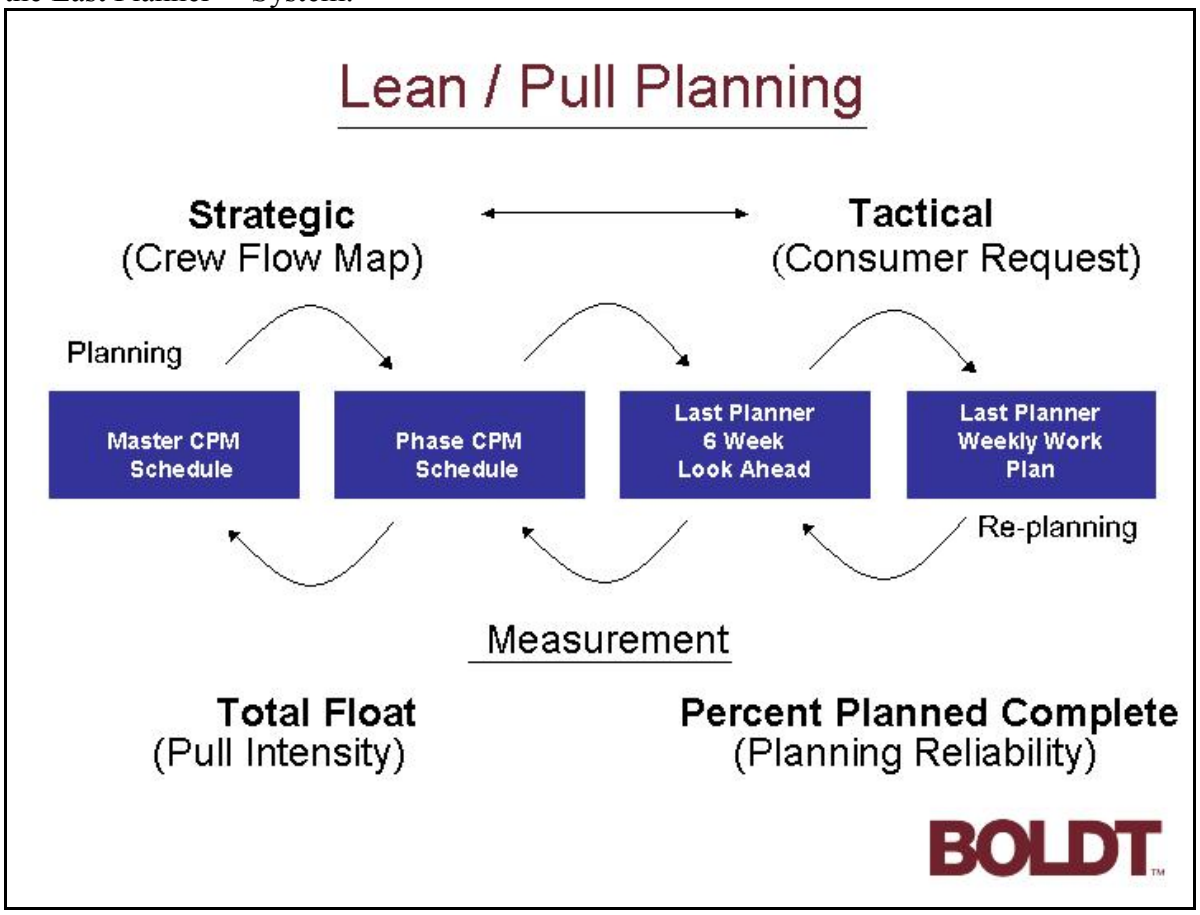

Figure 2: CPM and Last Planner planning cycle

In each case the planning is crew-centric and focuses on smoothing and stabilizing crew flow through the available made ready space. Making downstream space ready for future crew assignment requires not only the completion of work by other trades but also removal of all constraints including design, material deliveries, safety, access, shared resources, etc. The persistent idea is the stability of the crew and protection of its productive path forward. It is this persistent idea that sparks the interest of production managers and invites them into the ongoing planning discussion.

A SHORT HISTORY OF CPM USAGE AT BOLDT

Through the 80's and early 90's Boldt employed a small group of specialists to create, maintain and report progress on project schedules using the ubiquitous P3 software from Primavera systems. At that time Boldt held eleven P3 licenses and employed somewhat fewer specialists in its use. Scheduling was understood to be the responsibility of the Project Controls function at the corporate level. Access to the software and specialists was limited and required advance planning and coordination on the part of managers in order to meet the project's scheduling needs.

Responding to requests from field personnel for more control of their schedules in the mid-90's Boldt pushed the CPM scheduling function down to the laptop level by offering Primavera's SureTrak scheduling software to any employee who requested it. Training was provided on an as requested basis in the basics of CPM scheduling, float calculation and critical path analysis. Special attention was paid to formatting, printing and E-mailing; those functions representing our primary scheduling "face" to internal and external clients.

Central to Boldt's brand of CPM scheduling is a focus on strategic planning and a rapid turnaround from input to output. This culminated in 1994 in the development of a unique interactive scheduling style wherein we used a projected image of the active CPM schedule file to deliberately and publicly generate, quantify and allocate schedule contingency (float) by building and updating schedules in meetings attended by all project stakeholders.[3]

CONCLUSIONS

Applying the Lean ideal to CPM and focusing on crew flow, scheduling can find common ground with Lean Construction in a collaborative planning system. Discarding any assumptions about implied project management theory, we pick up CPM as a flexible tool and shape it to our needs.

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