

PROJECT MICROMANAGEMENT: PRACTICAL SITE PLANNING AND MANAGEMENT OF WORK FLOW

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ABSTRACT

Lean construction presents an opportunity for theory to mix with practical solutions to achieve efficiency in construction and to rethink the way things are done to improve production. This paper overviews the history of scheduling systems in construction and suggests that current Lean Construction Thinking is dominated by task-based approaches, such as Critical-Path, and that location-based scheduling techniques provide a promising alternative.

The flow of resources through locations, termed work-flow, and the resultant ability to control hand-over between both locations and crews, greatly empowers the management of construction from the perspective of day-to-day management of activities. The paper concentrates on the practical problems inherent in adopting theory and proposes new strategies for adapting scheduling systems for direct relevance to site management. The concept of micro-management is introduced, based on location-based scheduling. From this, a suite of strategies for managing sub-contracted work crews is developed, concentrating on location, work flow and site management. Principles for work planning and error management are proposed; including related procurement strategies.

KEY WORDS

Site management, Scheduling, Flow.

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INTRODUCTION

Project planning and scheduling systems represent a solution to structuring and managing the complexity of construction projects while accepting the vast variability between projects. The development of the theory of project scheduling took place well before Lean principles were identified, so the connection to a lean production epistemology remains largely ignored.

In the subsequent development of Lean Construction, the methods of project planning and scheduling work have largely been adopted from mainstream practice. The emphasis has been on developing a theory of Lean Construction and of developing strategies, tools and techniques for both the demonstration and the effective management of construction production. The result has been the effective adoption of an activity-based, critical path approach, with planning tools to improve reliability of planned completion of activities, set within a mainstream development of critical path scheduling techniques such as CPM, PERT, etc. Such thinking has largely been driven by the availability of relatively cheap and extremely powerful scheduling software. Critical path planning tools dominate this market, and effectively dominate construction planning, in both thought and execution.

Lean Construction Thinking, a term frequently used among researchers to describe the change in thinking from focusing on conversions rather than processes (Seymour 1996), demands a new approach to production planning and execution, and yet surprisingly this has been restricted to the dominant scheduling methodology. This represents a lost opportunity for expanding the suite of applicable tools to empower Lean Construction. The difficulty in applying lean thinking arises from the problem of identifying work-flow in a production system that is based around the discrete activities inherent in activity-based critical path planning and execution. As a result there has been intense focus on the identification of flow in a non-linear (production-line) process such as construction, and a somewhat obscure identification of flow as process – the non-production activities which deliver and release productive work, described as maintenance activities and regulatory activities by Seymour (1996). As a result, little effort has gone into solving the problem of physically creating flow in the production process. Instead the effort has gone into emulating flow through managing control systems and activity protection; the best known of these is the well developed but proprietary Last Planner technique (Ballard and Howell 2003). The result is that we now have some extremely sophisticated and powerful techniques to manage what we do (activity-based) when work commences on site. This is more commonly referred as work-structuring (Ballard and Howell 2003) and recent focus is moving to critique the dominance of work breakdown structures (Ballard and Howell 2003) which is so strong a part of task-based scheduling systems.

There is a great awareness of the importance of protecting planned work, and a growing awareness of the need to restrict work to only that which is required to release following work or to achieve hand-off, termed pull scheduling. “A pull technique is based on working from a target completion date backwards, which causes tasks to be defined and sequenced so that their completion releases work” (Ballard and Howell 2003). However, even the most recent work, with a few notable exceptions such as Kankainen and Seppänen (2003), remains dominated by the concept of an ideal logic network (Ballard and Howell, 2003). This is an

intrinsically task-based scheduling concept, carried through into sophistication as Phase Scheduling (summarized in Ballard and Howell, 2003).

It is also possible that the evolution of resource-adjusted scheduling has acted to entrench activity-based scheduling in the thinking of the lean proponent, as the apparent ability to manage resources appears consistent and supportive of a lean production epistemology. However, all forms of resource modeling incorporated in activity-based scheduling (aggregation, accumulation, allocation, smoothing and leveling) concentrate on the demands of the activity as a discrete event, and thus run counter to the aims of lean production, which demands flow of resources, and where as Huber and Reiser state (2003) “the primary function of scheduling and planning is to optimize production by concurrent management of crew flow and work flow”.

It is time to concentrate more effort on changing the way work is planned and managed in construction. This requires challenging the accepted industry practices built around activity-based scheduling and to look instead at location-based scheduling. Location-based scheduling has a long history, but has been largely hidden by the tendency to refer to it as repetitive-activity scheduling. It has also failed to attract the interest of software developers and so has remained a planning oddity, taught in most institutions but ignored in practice. Yet, in location-based scheduling may lie the keys to improving, or at least broadening, the suite of Lean Construction techniques.

A SHORT HISTORY OF PLANNING SYSTEMS

There are two main methodologies for scheduling work, both of which pre-date the development of the lean production epistemology, and thus remain to be clarified in this new environment: activity-based scheduling and location-based scheduling. These two methodologies in turn have many methods and techniques, often designed to achieve the same purposes in different ways.

The dominant scheduling technique is activity-based scheduling and it was first developed in the 1950s (Gordon and Tulip, 1997). The technique relies on the construction of a logical network of activities in three visual forms; activity on the arrow, activity on the node and logical dependency constraints (Dawson and Dawson, 1995), with four levels of complexity; deterministic (for example: CPM), probabilistic (for example PERT) generalized activity networks (Dawson and Dawson, 1995) and arguably the more recent critical-chain method (Herroelen et al., 2002). Gordon and Tulip (1997) have provided a fascinating clarification of the early commercial development of activity-based resource optimization, and the historical development underlying today’s software. They identify that resource optimization arose as early as 1960 with the following decade being the time of most significant development of resource modeling.

The sheer volume of research and development underlying activity-based techniques is daunting. It is no wonder that the resulting software dominates the industry. This volume may perhaps be best understood in light of the usual acknowledgement of the role of the USA military and also NASA in supporting the development of the technique. This origin is of more than passing interest for those interested in construction, as it suggests one reason why planners report difficulty gaining acceptance of their schedules on site, and instead rely heavily on controlling mechanisms for work-reliability (effectively using schedule-push).

Consider the typical military or NASA project. These generally revolve around single location assembly (such as a missile or space vehicle) of many complex and pre-assembled components, with assembly organized sequentially but with parallel execution – a context most suitably planned with activity-based techniques and yielding a critical path. The (oversimplified) character of ideal activity-based scheduling projects may therefore be described as:

- Dominated discrete locations
- Involving much pre-fabrication of components
- Complex assembly of pre-fabricated components, involving discrete activities
- Highly sequential, in that long-duration activities are not running simultaneously
- One of many critical paths may be identified
- Resource management is a time/resource optimization problem

Unfortunately, this list does not describe much of commercial construction at all well. This suggests that the research into scheduling techniques based around activity scheduling has not well served construction projects, which consist of large amounts of on-site fabrication involving continuous or repetitive work (including continuous processes involving pre-fabricated components), and in which the concept and reality of a critical path sits uncomfortably with most practitioners. In effect, the size of the tasks (the length of the line on the bar chart) leads to loss of control.

Some of these alternative characteristics of commercial construction align more closely with location-based scheduling, more frequently known as repetitive scheduling. Originally developed by the Good Year Company in the 1940s and expanded by the US Navy in the 1950s (Arditi et al., 2001), the suite of techniques has found strong support in continuous production systems (more typical in engineering construction) but only limited support in commercial construction. Harris and Ioannou (1998) summarize the various names (and sources) given to the variations in the method, including ‘Line-of-balance’, ‘Construction planning technique’, ‘Vertical Production Method’, ‘Time-Location Matrix model’, ‘Time Space Scheduling method’, ‘Disturbance scheduling’ and ‘Horizontal and vertical logic scheduling for multistory projects’. Interestingly they do not identify perhaps the most evocative term for a Lean thinker, that of ‘Flow-Line’ (Mohr 1991). Harris and Ioannou (1998) also identify the terms used in engineering construction such as highways, pipelines and tunnels, as ‘Time versus distance diagrams’, ‘Linear balance charts’, ‘Velocity diagrams’ and ‘Linear scheduling’. Kang et al. (2001) also identify ‘Horizontal and vertical scheduling’, and ‘Multiple repetitive construction process’ – but aims these at the specific case of vertical replication repeated in multiple buildings.

All these methods involve repetitive activities and for this Harris and Ioannou suggest a new generic term ‘Repetitive scheduling method (RSM)’. However the methods also strongly suggest location or place, and thus the use of the term ‘Location-based scheduling’ in this paper. The (oversimplified) character of ideal location-based scheduling may be described as:

- Multiple location, or more accurately multiple work places

- On-site and continuous assembly of components (including pre-fabricated work)
- Complex assembly involving repetitive but variable activities (work which repeats in different locations, but in which the amount or context changes)
- Equally parallel and sequential paths
- The critical path concept fails due to lack of control
- Resource management is a flow-optimization problem, to achieve flow of resources.

The link between planning work and Lean thinking appears to be supported by location-based scheduling. This arises from the increased ability, inherent in such techniques, to manage work tasks as they physically pass through the locations of a project. This focus on location greatly empowers lean techniques, for example giving much greater power to managing the planning, execution and release of work. In their application, however, they challenge the concepts of pull-scheduling, as resources are driven by flow-optimisation to reduce waste due to overproduction, rather than following the less structured principle of scheduling backwards or 'Last Responsible Moment Strategy' or Reverse Phase Scheduling' (Ballard and Howell 2003).

Before closing the discussion of the development of scheduling systems, it is worth canvassing critical chain scheduling. This relatively new approach, derived from the theory of constraints, has received great interest (Herroelen et al., 2002) and sometimes rates a mention as a Lean strategy, focusing as it does on protecting the critical path. However, critical chain scheduling does not extend beyond the underlying assumptions of task-based scheduling and its value in a lean-production approach must be limited.

FOCUSING ON WORK FLOW

An underlying assumption of location-based scheduling should be that resource constraints are driven by work flow, and that work completed in multiple locations will be treated as part of a continuous process. "It is... assumed that the same resource will be used for like activities in successive repeating units, and so each activity's resource must be consistent from unit to unit" (Harris and Ioannou, 1998). This continuation of an activity's resource across units of location is a powerful extension to construction planning logic ignored within traditional systems, where it is left to the site teams to manage work sequencing and location conflicts.

"Emphasizing production flow to achieve efficient but flexible operations is the essence of 'lean production' as described today". (Horman and Kenley, 1997) While it is very much part of the emphasis of Lean Construction, the reality is that work-flow management has not achieved widespread acceptance in the management of site activities. It is also true that seeking control of the flow of work is neither new nor, in some way, invented by Lean proponents. Construction companies are reported as having managed work flow and protected their work flow reliability from the 1950s. (Horman and Kenley, 1997) At that time it was considered common sense.

Managing resources with a priority on work-flow based on location is not new. However, the lack of appropriate software support for well understood tools has restricted the acceptance of this approach. There have been several attempts to achieve this effect using activity-based techniques such as CPM (Kang et al., 2001), including the concept of ‘crew-centric planning’ (Huber and Reiser 2003). However, manipulating the sheer quantity of information in a detailed schedule is scary; a 50 floor building with 10 apartments involving 50 activities necessitates managing 25,000 individually scheduled activities – possible to set up but a nightmare to manipulate.

Furthermore, a change in such a strategic component of the management of projects has significant implications. First, it has significant contract management implications, particularly implications for calculations of time delays. Secondly, it has significant practical implications. These require micro-management techniques to be applied.

IMPLICATIONS FOR DELAY CLAIMS

Critical Path scheduling has become so widespread in construction that a considerable amount of precedence has developed with regard to extension of times claims. Conlin and Retik (1997) reported that 52% of UK construction projects experienced delay claims of some sort. It is likely that all these claims would have involved some form of analysis of the critical path, whether by the ‘as-built’ technique, the ‘time-impact analysis’ technique or the ‘as planned’ technique (Conlin and Retik, 1997).

Anecdotal evidence suggests that the method of using the Critical Path to calculate delays is extremely frustrating to contractors, as it frequently does not reflect either the true impact, or the true consequence of change or delay. “Construction schedules cannot really identify the realities of actual site construction. This problem is caused by the construction planner or scheduler applying hard logic to a soft logic situation... Also, site operations may move to other locations or activities at other parts of the project before a given activity is completed.” (Conlin and Retik, 1997).

Such frustration reflects the conflict between CPM, with its activity priority, and the desire to drive an efficient project with work flow (location) priority. The latter requires that a delay claim consider the impact of delay on the continuous flow of work, and the cost implication on interrupted work, as well as the delay implication on following trades and project completion.

The key to interpretation of delay claims lies around the meaning of the critical path and the concept of float. Float is central to the analysis of activity networks in project management. “The float of an activity is an indicator of the extent to which the schedule can absorb delays in the completion of the activity without affecting its committed dates.” (Raz and Marshall, 1996). However, as Raz and Marshall go on to note, the interpretation of float is misleading if the management of resources is other than time-optimized.

Location-based scheduling highlights that with a flow-optimized resource constraint, the concept of float fails. More precisely, float is limited to consideration of free float only rather than total float. Free float is the amount of time that an activity may be delayed without affecting any other activity. Total float is broader and includes any delay which would not delay the entire project. Total float is a work-flow independent concept and has only limited relevance in location-based scheduling.

In location-based scheduling, the time delay questions which must be asked are:

- Does the delay disrupt the flow of a continuous activity?
- Does the delay impact on the flow of any following activities?
- Does the delay impact on the commencement of any following activities?
- Does the delay lead to the delay in project completion if flow is maintained?
- Can the delay be absorbed by interfering with the flow or pace of following trades such that the project is not delayed?

Thus it can be seen that in location-based scheduling the emphasis on delay consideration shifts from whether a delay is on the critical path, to the assumption that all activities are resource flow critical (meaning that, unless they are discrete, they must flow) and therefore are either impacted or will impact on the flow of following activities.

Following this assumption, different procurement paths are required to engage in work-flow priority projects. New precedents must then be developed to support the resolution of time-delay disputes.

LOCATION-BASED SCHEDULING

A commercial software package is now available to empower location-based scheduling, using the Line-of-Balance technique, and was presented at IGLC-2003 (Kankainen and Seppänen 2003). A more 'Lean' name for the technique displayed is Flowline scheduling. Figure 1 illustrates part of a typical schedule developed with this software.

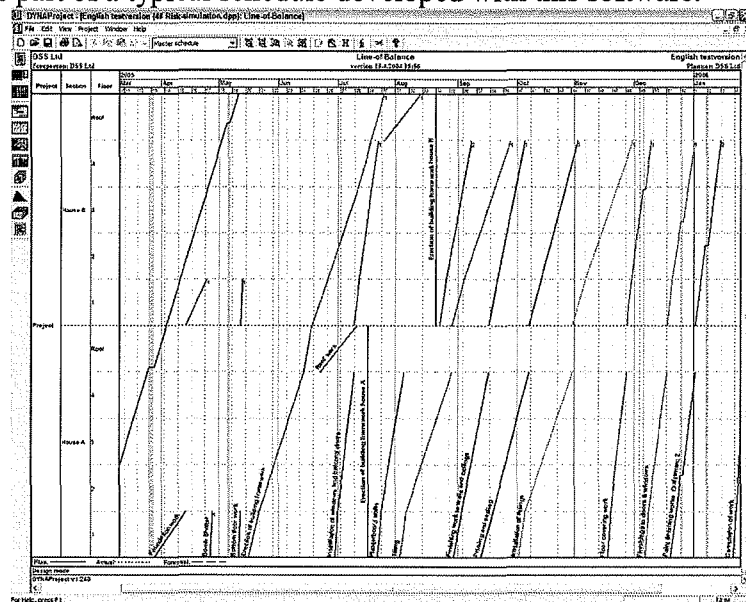


Figure 1: A typical Line-of-Balance schedule using DYNAPROJECT™

In Figure 1, work is shown flowing through locations (places) without disruption. This is a simple example, typical of the method outlined by Kankainen and Seppänen (2003), who

describe the use of DYNAPROject to manage projects strategically, including the use of buffers and sensitivity to interference, to manage workflow variability.

This approach may be termed 'macro-management'. The method described is a powerful project management and control system, allowing rapid and early development of project schedules based on location-specific measures of the building (bill of quantities with location data). Control emerges through the hand-over of locations from one work package to another (as in traditional techniques) as well as the hand-over from one location to another of the work-crew. The emphasis is on minimizing risk of disturbance by allowing buffers between activities and creating activities which are collective: that is, they are summaries of more detailed activities. These are to be subsequently broken down into more detail within the task, like a work breakdown structure.

Acceleration, through increasing gangs, works by altering the slope of the line-of-balance but this breaks the relationship between work and location.

Macro-management of projects does not address the real power of location-based scheduling techniques for managing work flow on site. For this objective, essential to ensure work-flow and equivalent to the detailed lean techniques such as Last PlannerTM, more detailed and work-focused planning is needed. This is termed here 'micro-management'.

MICRO-MANAGEMENT

The following is a brief description of the principles which should be applied in a location-based scheduling system to empower micro-management of projects. This is a focus on the level of detail which becomes intuitive to site personnel, thus addressing one of the major flaws with project scheduling: the failure of site personnel to understand, implement and manage a project schedule. Anecdotal evidence suggests that project scheduling is almost universally failing when it comes to communicating the management of a project beyond the Project Manager to general site personnel. Stories abound of the schedules being used as wallpaper!

PRACTICAL SITE IMPLICATIONS

The most important element of a location-based schedule is that it provides information about the location of work and work crews. From this comes the ability to manage the work to ensure work flow, work reliability, avoidance of interference, improved quality and reduced rework. The principles to be applied to location-based scheduling follow, together with a discussion. These principles are for micro-management, and are to ensure the most practical site communication to protect work flow and performance reliability.

Location

A schedule should indicate the location. For site operatives, it is extremely powerful to know the precise location of a work crew. Consider the situation where there is a 50 level building with ten apartments per level. That is 500 locations where you might find a work crew. It is possible that with that many locations, a poorly organized supervisor might never even enter some of those locations. It certainly provides a lot of opportunities to hide or work out of sequence.

Scheduling the precise location of a work crew, particularly if there are multiple crews, minimizes site management problems. The chart indicates where crews should be on a given day. It is then a simple matter to monitor location performance. Crews in the wrong place can be rapidly corrected.

Location requires the following capacity in a computer assisted schedule:

- All activities must belong to a location,
- Location may display in a hierarchy, but only where there is a physical reality. For example, apartments logically exist within floors and floors exist within buildings, so it is logical that work done in an apartment is also displayed within a floor and in turn in the building.
- Location should be logical. For example excavation should not 'appear' in the upper floors. Thus activities should be constrained within their logical place. Thus a 'site' location or a 'project' place can be used to isolate work into a logical location.
- The indication of a line (for an activity) in a location, should correspond to a physical presence of a work crew. Thus enabling rapid identification of conformance.
- The boundaries of the diagrammatic representation should represent the physical boundaries, to visually identify interference. For example, the architectural documentation standards which indicate the top of finished floor as being the commencement of a new level should correspond to the graphical representation in the schedule. This ensures common annotation, and also ensures that floors and their associated temporary support structures exist within the physical interference space.
- Gangs may be multiplied, with computer directed location optimization
- Multiplied gangs should be represented as multiple parallel lines, with the slope representing the productivity of a single gang. This allows manipulation and identification of the physical location. This level of detail is not required for macro-management.

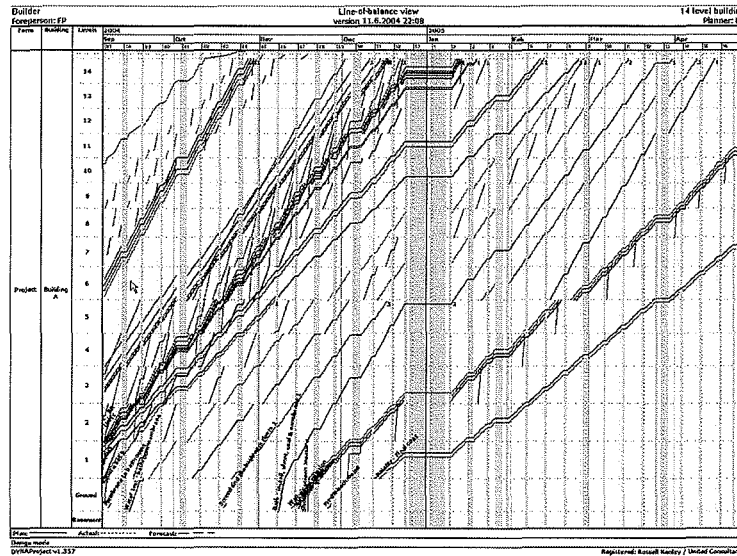


Figure 2: Micromanagement schedule

An example chart showing a detailed micromanagement schedule is illustrated in Figure 2. This shows a schedule with no time or space buffers between activities (activities as a whole are all critical). This clearly illustrates the flow of work crews through locations.

Work flow

A schedule should indicate, manage and protect work flow. This allows the management of projects according to Lean concepts, including work flow, production reliability, supply chain management and just-in-time delivery.

Work flow requires the following capacity in a schedule:

- Continuity of work crews should be optimized and displayed
- Work flow must be able to be forced (continuous) or broken depending on strategic choice. Some activities are flow sensitive, some are not. Others are flow sensitive but can be broken strategically to allow following trades to catch up.
- Gang multiples must be able to be used to suit the strategic needs of the project, not a forced change. For example, it is often useful to go slow at the start of an activity and then to increase speed by increasing gangs. Another use is to allow for learning curves (Arditi et al., 2001; Amor, 2002) by starting with multiple gangs and then reducing gangs as productivity improves, to maintain a steady rate of flow.
- Work flow must be able to change the sequence of location without disrupting the underlying precedence logic. For example, a faster trade (than its successors) might take advantage of space-buffers to work in another building until required again, thus enabling the successor trades in that building to commence.

Site management and controlling progress

It is critical that any scheduling system communicates rapidly and effectively with the site team. Location-based scheduling enables just such communication and it is this level of detail which enables control. More importantly, however, it resolves many areas of dispute in the management of a project. No longer is work flow and sequencing a matter of strength of will of project managers versus subcontractors. Now it is clearly documented and sequenced. There can be no dispute about where work crews should be physically located, and especially where they should NOT be.

This empowers detailed control of the work as well as empowering monitoring and reporting of progress and the taking of corrective action. The features of a schedule to provide this critical component of a project are:

- The schedule should clearly indicate who should be where and when
- Deviation from the schedule should be highlighted at the location level of accuracy, allowing rapid identification of required control actions
- Control actions should allow acceleration to restore schedule, delay acceptance and resultant activity delay, and earned value interpretation. Micromanagement recognizes the immediate impact of a delay (in the absence of buffers) and manages that impact on following trades. This requires careful procurement and subcontractor management.
- Both resource flow and work flow are explicitly addressed, as work crews are ensured available locations to move to, as well as readiness for that new location for their work.

PROCUREMENT IMPLICATIONS

While procurement management is a necessary part of a project for the reason that it enables timely execution of the works, it is even more important to reconsider the types of agreements being used.

Existing agreements largely revolve around activity-based schedules and there is no specificity regarding location and sequence of the work. In other words, subcontractors are not forced to work in sequence, as the level of detail usually only specifies earliest start, latest finish and activity duration. Sequence of work through the internal multiple locations is usually not addressed contractually. This leads to dispute in measuring progress. More importantly, contractors feel no need to manage for work flow, instead transferring the cost on to subcontractors.

The most significant cost reductions will arise when the procurement systems are matched with micro-management of the construction work using location-based scheduling techniques.

CONCLUSION

Location-based scheduling techniques, which have as great a heritage as activity-based scheduling, provide powerful techniques for planning and controlling the flow of crews and

work through a construction project and its multiple locations. In systems such as Flow-line, resources are optimized for flow, rather than for time or resource constraints.

Micro-management techniques allow for location to be used as a site management tool, combining ease of communication with the ability to control the hand-over of work between activities and through locations. This mechanism has the potential to provide a powerful aid to achieving greater acceptance of lean construction.

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