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Reliable Schedule Forecasting in Federal Design-Build Facility Procurement

Timothy Gannon[1], Peter Feng[2], William Sitzabee[3]

Abstract

Research Question: Do initial schedules provide reliable forecasting for project control?
Purpose: The purpose of this research is to understand how scheduling works in federal facility procurement and identify how project change underscores schedule uncertainty.
Research Method: Comparative analysis of project schedule data from three case studies.
Findings: This paper documents how initial project schedules fail to sufficiently forecast and provide a reliable baseline for total cost, final duration, and activity count for three design-build projects. Most schedule variability occurs after the 100% design benchmark. Activity growth highlights scheduling challenges encountered by the construction managers and general contractors (GCs).
Limitations: The research considers three military construction projects managed by the United States Army Corps of Engineers (USACE) on Wright-Patterson Air Force Base, Ohio.
Implications: The research indicates a need to reexamine federal design-build schedule specifications and management practices in the pursuit of project control.
Value for Practitioners: This paper discusses reliability concerns in activity-based scheduling and promotes an application of lean thinking to public sector construction management.
Keywords: scheduling, production control, lean construction, federal facility procurement, public sector construction, construction management
Paper type: Full paper

Introduction

Construction engineering managers participate in a multifaceted process riddled with technical and social pressures. According to the Accreditation Board for Engineering and Technology (ABET), engineering management programs must prepare graduates to

1 Masters Student, Graduate Engineering Management, United States Air Force Institute of Technology, Dayton, OH, 45433, USA, timothy.gannon@us.af.mil
2 Ph.D. Civil Engineering, PE, USAF Lt Col, Assistant Professor, United States Air Force Institute of Technology, Dayton, OH, 45433, USA, peter.feng@us.af.mil
3 Ph.D. Civil Engineering, PE, USAF Lt Col, Assistant Professor, United States Air Force Institute of Technology, Dayton, OH, 45433, USA, william.sitzabee@us.af.mil

understand the relationships between planning, organizing, leading, and controlling (ABET Engineering Accreditation Commission 2010). Overall, these four tasks facilitate the structuring and execution of work. In this manner, scheduling is an important process that network tasks in order to communicate what should happen in the future.

> *"Schedules are those outputs of work structuring that link directly with production control."* (Ballard et al. 2002)

Federal design-build (DB) facility procurement involves several factors that influence the scheduling process. First, government agencies must maintain fair and competitive bidding of DB contracts in accordance with the Federal Acquisition Reform Act of 1996 (Public Law 104-106) (American Society of Civil Engineers 2010). Consequently, public construction operates in a uniquely regulated acquisition environment in pursuit of transparency and equity. This pressures a construction schedule to provide reliable records of contract progress and payments.

Next, in terms of planning and project delivery methods, schedulers deal with more unknowns at the beginning of a DB project than a traditional design-bid-build process since DB contracts typically present no more than 35% design in a proposal. DB contracts feature concurrent development within the design and construction phases, which can generate technical and behavioral tendencies described as the "90% syndrome" and the "Liar's club" that contribute to schedule degradation (Ford and Sterman 2003b; Ford and Sterman 2003a). This is the condition of stagnating around a 90% completion plateau on a project and the associated behavior of hiding rework or fault in the hold. Although DB proponents may laud the synergy created in coupling processes and responsibilities under one contractor, social factors can play a major role in project performance. Accordingly, a 2010 construction management literary review conducted by Xue et al. finds that success in collaborative working within the construction industry predominately hinges on two factors: the business environment and human behavior.

By design, DB projects tend to shift more risk and liability to the general contractor (GC) and potentially forego a degree of owner participation (Agostini 1996). In this way, DB can offer a quicker contracting solution with possibly less end-user coordination. Although this method may produce a reduction of owner control, careful schedule and cost review practices are measures noted to "bridge the gap" needed in federal management oversight between owners and contractors (Rookard-Everett 2009). Overall, the federal government pursues DB contracts to most expediently allocate funds and maximize budget execution. As such, schedule communication remains a critical management process.

Schedule communication fundamentally rests on the problems of planning. Production theory addresses these problems through a comparison of pushing and pulling methods (Spearman and Zazanis 1992). In this research, pull systems reveal advantages in control and reliability for manufacturing. However, obstacles exist in implementing pull techniques to construction, especially with design components (Ballard 1999). DB construction management may present challenges to combine the techniques to facilitate realistic schedule forecasting. In order to understand what is happening on real projects in regards to reliable schedules, we investigated three different cases.

This research considers the following military construction projects on Wright Patterson Air Force Base, Dayton OH:

- Project 1: DB addition/alteration of Signature Technology Laboratory (New construction attached to existing)
- Project 2: DB alteration of Acquisition Management and Materials Laboratory Facility (Renovation of two separated buildings)
- Project 3: DB addition/alteration of Sensors Directorate Laboratory (New construction and Renovation of multiple facilities)

United States Army Corps of Engineers (USACE) provides construction management services for nearly all Air Force construction over $750,000 (USD). For these observed projects, USACE uses contract specifications to outline requirements of a detailed activity-based schedule. USACE mandates a standardization of activity codes for schedule submittals and links the pay application to reported progress per submittal. The initial schedule, required no later than 40-42 days after the notice to proceed, serves as the baseline for monitoring this progress (United States Army Corps of Engineers 2007). Thus, managing scheduled activities is USACE's basis of maintaining contractor accountability.

The question considered in the paper: Do initial schedules specified in federal design-build facility procurements provide reliable forecasting for project control?

Following a review of the objective and limitations, this paper provides case project descriptions to identify stakeholders, scopes, and complexities. We then present the research question and methods. Next, the analysis and results expand on our findings of schedule variance and shortfalls. The recommendation section then provides a concept to address the variance. Finally, the conclusions section discusses the overall schedule shortfalls and impacts.

Objective

The objective is to understand how the scheduling process performs for each of the three projects and identify how project change underscores schedule uncertainty. The metrics of total cost, total duration, and activity count allow us to analyze data from the initial schedules verses the subsequent schedule updates. These metrics illustrate the forecasting shortfalls in the activity-based scheduling currently used in public sector construction management.

Limitations

Federal facility procurement is a massive industry for which we only examine three project case studies. This research is limited to Wright Patterson Air Force Base, Dayton Ohio. The project contracts are all design-build, which is most common for projects of this magnitude. We monitored project progress and scheduling issues with construction managers on an average of 2 times a month over the course of 14 months (September 2009-November 2010). The Primavera P6 XER schedule data files were available for a total 61 updates between the three projects combined. Human input errors inevitably exist in these files as well.

Case study project descriptions

The prime contractor for all the case study projects is Butt Construction Company (BCC) with award dates between June 2008 and April 2009 after competitive bidding processes. The individual project descriptions below are in chronological order according

to award date. Coincidently, this is also the order of contract award price, smallest to largest, ranging from $8.5 million to $36.2 million (USD). The facilities are all located within a 1km radius and managed by the local USACE construction services office, which is located within this radius as well.

The USACE and BCC management personnel vary on the three projects with some overlap. Following are the staffing differences and similarities for key positions between the projects:

- Different USACE project managers (although some overlap due to transfers)
- Different USACE construction management project engineers
- Different USACE quality assurance representatives
- Different BCC project managers
- Different BCC quality control and schedule managers
- Same USACE resident engineer
- Same USACE senior project controller
- Same BCC project engineer

The Department of Defense (DoD) Base Realignment and Closure (BRAC) 2005 process spurred the funding of all three projects. These BRAC facility procurements each support a high priority movement of a diverse group of Air Force personnel and operations upon completion. Therefore, the motive of construction across the projects is similar although the end-users are different. The descriptions below provide further overview of each project's contract requirements and challenges.

Project 1

This DB contract for the addition/alteration to the Signature Technology Laboratory, awarded on 12 June 2008, was $8,540,000 with an original performance period of 540 calendar days. The contract consisted of new construction of a three-story office building attached to an existing facility along with new parking. In adherence to security requirements, the new building had no windows and entailed multiple Sensitive Compartmented Information Facility (SCIF) rooms. The new constructed area totaled approximately 3,700 square meters (40,000 square feet (SF)). Near the completion of the project, the only major contract modification included the $300,000 (USD) change order for finishing floor three.

Project 2

This DB contract for the alteration of Acquisition Management and Materials Laboratory Facility, awarded on 22 Sep 2008, was $18,539,000 with an original performance period of 570 calendar days. This renovation entailed new structural, electrical, and HVAC systems for two separate buildings both built in the late 1920s. The acquisition management facility renovation incorporate about 6050 square meters (65,000 SF) of office space while the materials lab was nearly 2790 square meters (30,000 SF). One of the main challenges was to update the buildings to the DoD Anti-Terrorism/Force Protection standards. This included new window, wall, and structural support designs to mitigate blast hazards. The materials laboratory also required specialized equipment and air quality standards for experimental use. The largest change to the contract was the

addition of finishes to the bottom floor and office furniture installation for all three floors of office space in the acquisition management facility.

Project 3

This DB addition/alteration of Sensors Directorate Laboratory, awarded on 27 April 2009, was $36,212,000 with an original performance period of 690 calendar days. The contract required new construction of an office building, storage warehouses, and sensors testing range along with eight different renovation areas for laboratory and office space totaling 13,750 square meters (148,000 SF). The project entailed integrating detailed laboratory needs into the final designs of the renovations and relocating personnel into temporary office space during construction. This expanded interface with the end-users created a challenge to deliver requirements and execute ongoing refinements.

Research question and methods

This exploratory research asks the question: do initial schedules provide reliable forecasting for project control? In order to understand this inquiry in the context of federal DB facility procurement, we first investigated the general scheduling process used by a local USACE office. We used specifications and the schedule data from periodic updates to extract the details of cost, duration, and activities to evaluate consistency between projects.

We used comparative analysis of this schedule data to understand the variability encountered in the updating process. Our approach to capturing project information entailed many conversations with management personnel from both USACE and BCC along with visits to the project sites. The core of the research relies on the examination of Primavera P6 schedule files, schedule narratives, contract schedule specifications, and presentations on USACE scheduling requirements. In the pursuit of organizing this information into applicable findings, we performed the following steps:

1. Outlined and characterized scheduling process (using value stream mapping)
2. Gathered schedule data
3. Analyzed change and trends in cost, duration, and activities
4. Identified timing of changes relative to percent schedule and design complete
5. Employed qualitative root cause analysis on the changes

As described by Creswell (2003), the framework of our inquiry rests on a mixed method of quantitative and qualitative strategies. Using concurrent procedures of research, the observed schedule metrics merges with the gathered observations from project managers to form an understanding of the overall results.

Analysis and results

We discovered that the three projects had consistent requirements. The contract specifications clearly set the same expectations. However, the process as a whole involved multiple handoffs using redundant information systems. The value stream map revealed a possible problem with the information exchange for schedule updating. In this exchange, the general contractor (GC) first produces schedules in Primavera P6 software, but then must upload schedules to USACE's Quality Control System/Resident Management

System (QCS/RMS) in order to complete a pay application. Even though the USACE project manager primarily uses the QCS/RMS information to verify project status, the GC must still submit a hard and soft copy of the Primavera P6 schedule file along with a schedule narrative for the review by the project controller. Waste, therefore, exists in the maintenance of multiple lines of schedule communication. Opportunity for inconsistent data using multiple incompatible systems is a documented challenge (Rasdorf et al. 2009). The information and communication technology study conducted by Lam et al. (2010) reveals a similar redundancy of electronic and hard copies used by multidisciplinary teams throughout the construction industry (Lam et al. 2010).

In all three projects, the GC managers also meet challenges in integrating potential modifications or options in the schedule updates. Per the schedule specifications, contract modifications cannot be included into the official schedule until approved. This drives the official schedule to carry unsound planning of cost and activity logic in several instances. In terms of work execution, GC project managers commented, "we really need to keep two schedules: one for USACE to show no changes, and one for us to implement the items necessary to complete the changes and stay on schedule." This conflict creates a chance to introduce waste and error in the data. The intent for the GC was to use the schedule as a management tool verses a reporting device. However, the demand to communicate compensation for unapproved work led to a variety of schedule approaches by both the USACE and BCC managers. For example, Project 1 began tracking a major change order on a separate schedule and later included it on the final schedule updates. On the other hand, Project 2 rearranged sequencing in the schedule and then delayed a correction of the cost loading until given approval of the change. Project 3 initially reported unapproved modifications on the schedule as floating activities without finalizing sequencing logic until USACE officially awarded the options. Despite the unique circumstances, the friction in developing a schedule update to acknowledge a cost incurred for an unapproved change is a recurring issue in each project.

Change in these projects originates from the following sources:

- Owner/USACE driven contract modifications
- Definition and sequencing clarification/correction
- Delays from weather and material delivery
- Hidden rework from uncertainty ("Liar's club")
- Process learning

Further schedule analysis quantifies the amount of change incurred in terms of cost, duration, and activity metrics. Table 1 summarizes this analysis of the project schedule data. For all three projects, the summary shows a cumulative growth using each metric of cost, duration, and activity count when comparing the schedule updates to the initial schedule. The calculation for the percentage change is total change reported in the schedule updates divided by the original value. For instance, the 7% total cost growth for Project 1 is calculated by subtracting the original contract cost ($8,540,000) from the last scheduled cost ($9,104,448) and dividing by the original contract amount ($8,540,000) and multiplying by 100.The values for original cost and performance period come directly from the awarded contract, whereas the initial number of activities originates from the initial schedule created by BCC in accordance with USACE schedule requirements.

Note that cost growth and duration growth are not synonymous with cost overrun or behind schedule, respectively. Government change in the contract drives most of the

variability. Meanwhile, the activity count parameter captures the evolving nature of the scheduled events. The increase in activity count reveals the detailing of the schedule and indicates a new formation in planning and project change. Although the Lean community views this process of detailing as a favorable way of including production level tasks, the public sector maintains that the initial schedule is a contractual anchor point. Thus, activity count variation is problematic.

Table 1: Summary of Schedule Analysis

	Project 1	Project 2	Project 3
Original Project Amount	$8,540,000	$18,539,000	$36,212,000
Total % Cost Growth((Last scheduled total cost – original cost)/original cost)*100%	7%	4%	41%
Original Performance Period (Cal. Days)	540	570	690
Total % Duration Growth((Last scheduled total duration – original duration)/original duration)*100%	29%	10%	7%
Initial Number of Activities	331	544	1084
Total % Activity Growth((Last scheduled activity count – original activity count)/original activity count)*100%	31%	31%	44%

Project 1 and 2 schedules report an overall 7% and 4% increase in scheduled cost, respectively. Although contract modifications justify these increases, they are still within a feasible contingency budget estimate of 7.5% as predicted by a recent Air Force construction cost model (Thal et al. 2010). The Project 1 and 2 cost growths also fall within one standard deviation of another cost model of public construction developed in Jordan (Hammad et al. 2010). The 41% cost increase from project 3 is a result of cumulative options as well as major modifications. The schedule originally removed the numerous options then added them back following each official approval of change. At the time of writing, Project 3 is in progress and undergoing further change in the overall scope and budget.

The positive duration growth may indicate a noncompliance to the contracted performance period. However, owner modifications to the contracts have created extensions to the must finish dates for all projects. Project 1 reported an increase of nearly 160 days to complete the finishes of an additional floor. Contract changes including office furniture and floor finishes attribute for most of the growth in Project 2's duration. Finally, the 7% increase in time on the Project 3 schedule is a result of executed options and durations linked to new activities.

Finally, activity growth seen in table 1 above signifies an increase in the number of tasks tracked in the progression of schedule updates. The table reports a task expansion of 31% for Project 1 and 2 and 44% for Project 3. According to the USACE DB contract specifications, remaining construction activities are to be included with cost loading by the completion of the design phase. Within this time, managers can anticipate a degree of

change. However, timing analysis of activity change indicates that the majority of activity growth occurs after 100% design.

Figure 1 shows the amount of cumulative activity growth in relation to the schedule percent complete throughout the performance period. The horizontal axis represents time in months after the notice to proceed. Using the left vertical axis as its reference, the solid line represents the schedule percent complete according to the progress updates through time. The right vertical axis provides the reference for the cumulative activity growth graphically depicted by the dashed line in the figure. Together, the figure shows the relative timing of activity growths for each project.

The activity growth in Project 1 shows an increase of over 80 activities in the last months of the project. These activities relate to the finish of floor three; however, the approval of the change order delayed the actual inclusion of this work in the official project schedule. The GC manager instead tracked the work on a separate schedule to avoid misrepresenting the contract. In turn, the initial schedule does not include a means to monitor the progress of this final phase. Consequently, the schedule exhibits a plateau of the schedule percent complete just below 100% for the last six months.

Activity count variance from the initial schedule in Project 2 occurs mostly before the design is complete. Even so, the cumulative growth shows another increase approximately six months after the 100% design. The GC manager also reports zero schedule completion for the first five months. This anomaly is an error and a result of a manual update of the schedule submittals into the USACE QCS program instead of tracking correctly in the P6 files. The activity growth is a result of both a fleshing out of the schedule during the design and incorporating owner changes during the contract performance. Project 2 is unique from the others in displaying a small drop in the growth at month 15. This indicates a removal of activities from the schedule. Even so, growth continues and the initial schedule becomes more unreliable in monitoring progress.

Finally, the cumulative schedule activity growth for Project 3 indicates considerable deviation from the number of activities planned in the initial schedule. Sixteen percent of cumulative activity growth occurs within the design phase. The recorded project shows an additional twenty-nine percent activity growth after the design completes. Note that the project is still in progress and is prone to further changes to the activity count based on the trend. The Project 3 graph indicates growth in every periodic schedule update provided. Again, options awarded within the performance period of Project 3 help shape the changes of activity counts.

Despite the differences in project requirements and management personnel, the scheduling process is similar. Missing schedule submittals reveal gaps in the percent schedule complete and activity count trends seen in Figure 1. Yet the graphs still clearly present evidence that the number of activities increases throughout the project and that the design development accounts for only a fraction of this change. The growth in total activities requires additional effort from the GC to maintain and USACE to review. The upward trend of activities in all three projects indicates that schedules transform throughout the projects despite the establishment of a single baseline specified in the beginning. Although this initial schedule is required within the first two months, these DB contracts do not reach 100% design until the 8-11 month point. Moreover, a third or more of the activity growth occurs months beyond the 100% design. Consequently, these project

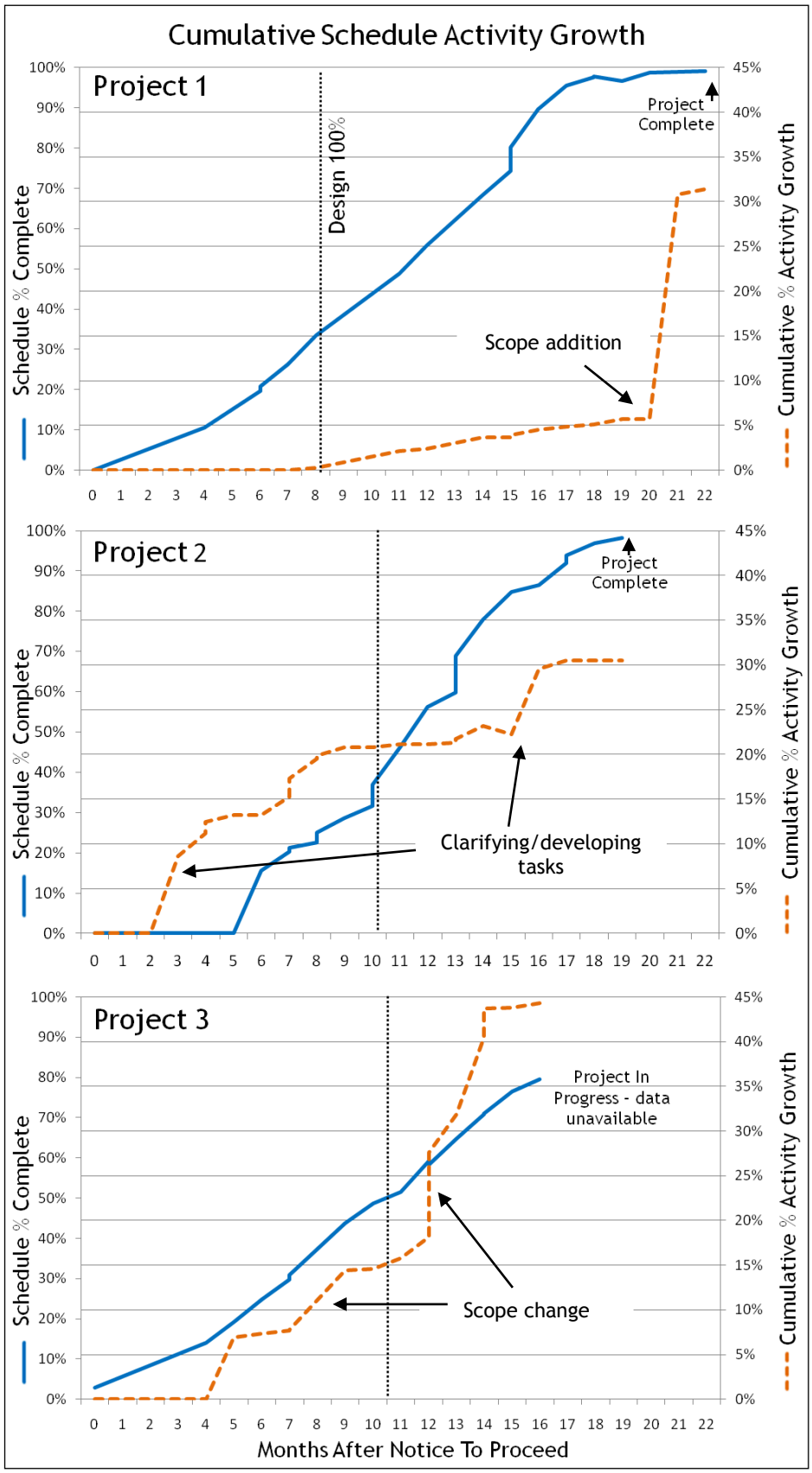

Figure 1: Cumulative schedule activity growth

schedules appear dynamic in the attempt to capture unexpected modifications throughout the performance period.

Recommendation

Given the unintended dynamics observed in activity-base scheduling, our recommendation is to change specifications in federal facility procurement contracts in pursuit of more reliable forecasting. The goal is to allow a schedule to adjust according to expected uncertainty while maintaining control. As seen in the cone of uncertainty in Figure 3 below, the variability early in a DB project at 35% design is much greater than later at 100% design.

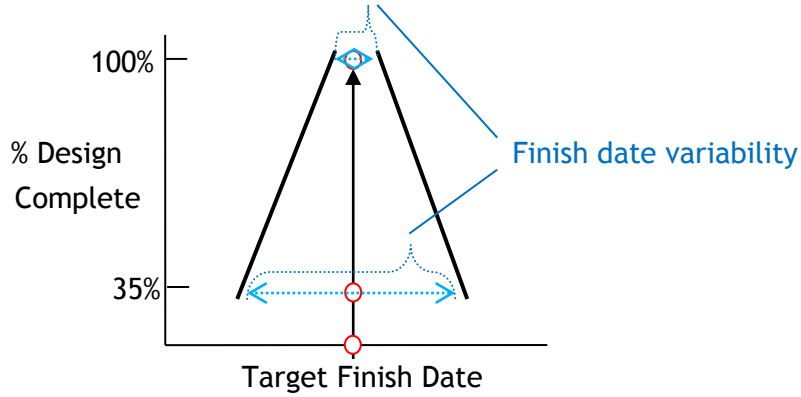

Figure 3: Cone of uncertainty

The target finish date on the horizontal axis acts as a surrogate for any target schedule metric such as cost, duration, or activity count. Thus, when a design is only at 35%, a project manager can expect the variability around a target metric to be large. Based on the case studies, the accuracy of the initial schedule at roughly 35% design ranges 4-44% depending on the metric. However, as more design is completed, the cone narrows shaping a reduction in the level of project uncertainty. In the cases explored, the schedules at the 100% design mark show a reduction of 50% in the variability. Production changes still occur due to unexpected planning and this needs to be known and worked by all stakeholders.

The timing in establishing a phase baseline determines the amount of uncertainty the schedule will carry and potential for rework in actual activity execution. Accordingly, Feng et al. (2008) demonstrate how rework timing affects a project as a whole; by delaying final plan and work in order to resolve unknowns, the overall time required for negative rework decreases.

As a foundation to the change, production theory and lean thinking offers an innovative perspective to the construction industry by promoting a simultaneous adherence to the principles of transformation, flow, and value (TFV) (Koskela 1992; Ballard 2000; Ballard et al. 2002). In particular, the Last Planner™ System (LPS) focuses on these TFV goals to provide production control in the scheduling process (Ballard and Howell 1998; Ballard 2000; Ballard and Howell 2003). LPS also embodies a "management by means" foundation of thought by addressing internal goals and metrics through "percent planned complete" of weekly work (Kim and Ballard 2010). Kim and Ballard discuss how

the LPS concept thus better suits an operational level of work such as the daily construction management endeavors where "each task is highly interdependent."

LPS incorporates four levels of planning as seen in Figure 2 below:

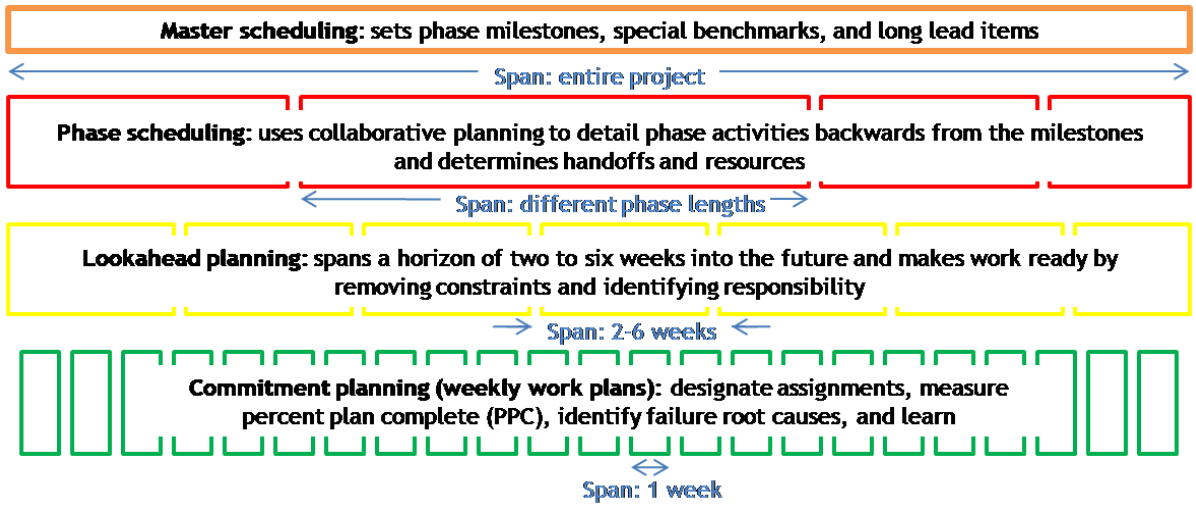

Figure 2: Levels of schedules

Using these four levels or planning, management can structure work using the most recent information and provide reliable workflow with pull techniques and active conflict resolution. Planning therefore integrates changes into the schedule updates. As the time of execution nears, details explode and the basis for measured progress is a current set of promises or goals. The Last Planner™ system provides an alternative scheduling method applicable to the public sector but must be carefully implemented in DB projects.

More specifically, our recommendation involves using relational contracting to establish progressive phase schedules aimed at target value designs. Relational contracting provides a way to share risk and commitment through strategies of target value design, collaboration, holistic thinking, and learning (Lichtig 2005). In this way, the schedule specifications could still call for a master schedule to provide a target value design and needed end-date and important milestones to the end-user. The master schedule is the skeleton of the baseline. However, the payouts to GCs coincide with progress in the more flexible set of phase schedule baselines that correspond with the development of the design and execution planning. The GC would withhold phase schedules until the design approvals at 65%, 95%, and 100% and develop progressive phase baselines aimed to include all changes in the early stages. In doing so, we defer more decisions until the last responsible moment and consequently strengthen the reliability of the schedule for the remainder of all planning, organizing, leading, and controlling tasks in management.

Several obstacles still exist in a progressive baseline approach. Without the correct incentives and contractual conditions, liability and transparency is a concern for the government. The perceived risk is higher if the government accepts an incomplete or flexible type schedule in the beginning of the project. The transformation of the phased baseline schedules could provide GCs with an opportunity to make unaccounted changes. Yet, the implementation of the bottom tiers of the lookahead and commitment planning offers the connective tissue most important to the monitoring of the plans and production.

Scheduling, in this way becomes a pull system controlled by the production team to support the hard constraints of the project. Contractual completion dates can therefore be set while internal execution is more fluid. The four levels of schedules used together reinforce the trust and learning needed to execute positive control and ultimately provide more reliable forecasting.

Conclusions

Uncertainty challenges construction managers throughout the scheduling process. The initial activity-based schedules from the case study projects reveal shortfalls in forecasting:

- Final project cost
- Final project duration
- Total activity count

The growth in these metrics indicates that uncertainty in the beginning of the projects is unavoidable. Although creating a baseline early may establish an indicator of project plan and scope, the encountered modifications can quickly deem the efforts obsolete. Since change happens, it should be incorporated progressively. The activity growth in particular warrants concern of GC managers since USACE expects them to justify deviation from the initial schedule and convey positive control. The schedule specification mandates a submission of reasoning and solution with any behind schedule activities (United States Army Corps of Engineers 2007). Accordingly, the added work of explaining reported activities does not contribute to any of the lean goals of transformation, flow, or value.

Pursuing lean goals in public facility procurement could make a major impact on the entire construction industry.

Although initial activity-based schedules seemingly provide a comprehensive and networked plan in which to monitor project progression, a different approach to capture change appears necessary. Detailing work breakdowns and critical paths in the beginning of the project does not provide a reliable baseline. If the project does use initial schedules as baselines, change disturbs efforts to monitor realistic outputs. In this way, updates deviating from the baseline schedule require continual justification. At the same time, known contract changes cannot be included in the schedule until official approval, which pushes the uncertainty into the future. Ultimately, the scheduling required by USACE only facilitates as supporting documentation for payment applications but is misaligned for project control.

Balancing the financial investments and risks of a facility project against the progression of completed work is a key management mechanism for those overseeing federal procurement. On the other side, general contractors are obliged to show a plan to accomplish work and receive compensation through an initial schedule. However, if the initial schedule fails as a suitable baseline because of change, change ought to be integrated into project management from both sides of the contract. Together the government and contractors can work to pull scheduling into place rather than push. Since the unknowns for DB projects are unavoidable, the four-tiered planning approach of the Last Planner™ system may provide the only viable option. At the least, schedule

specifications need to acknowledge a demand for a progressive baseline that responds quickly to change. Overall, controlling uncertainty can provide more reliable schedule forecasting and project control.

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Disclaimer

The views expressed in this paper are those of the authors and do not reflect the official policy or position of the United States Air Force, The Department of Defense, or the United States Government.

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