



**UNDERSTANDING SCHEDULE FORECASTING SHORTFALLS IN FEDERAL
DESIGN-BUILD FACILITY PROCUREMENT**

THESIS

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AFIT/GEM/ENV/11-M02

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Abstract

Design-build contracts for US federal facility procurement require an initial project schedule outlining the performance period to be submitted within forty-two calendar days after the notice to proceed. This initial schedule is used to evaluate the periodic schedule updates throughout the project duration as a means to determine payment and assess project control. This research seeks to understand how the schedule update process works and how it performs in forecasting total project cost, activity count, and project duration.

Using three design-build military construction (MILCON) projects as case studies, this research examines the uniformity of scheduling practices and measuring each project's variability between schedule updates and the initial schedule. First, this thesis provides the project description and basic contract parameters. Production theory (transformation, flow, and value) forms the foundation of the literature review used to map the general schedule update process. Employing a comparative analysis, Primavera P6 schedule data is compiled to expose the changes made in each update. Finally, root cause analysis is used to account for the changes.

Applying the initial schedule as the baseline measure for the entire performance period proves problematic for the studied projects. The results show the following overall deviations from the initial schedule: 1) cost growth ranging from 4% to 41%; 2) activity growth ranging from 31% to 44%; and 3) duration growth ranging from 7% to 29%. This unplanned growth may indicate deficient project control and a need to revise schedule specifications and practices.

AFIT/GEM/ENV/11-M02

To my wife

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UNDERSTANDING SCHEDULE FORECASTING SHORTFALLS IN FEDERAL DESIGN-BUILD FACILITY PROCUREMENT

I. Introduction

Background

Federal facility procurement is a critical mission support effort. Government investment in facilities provides personnel the needed shelter to perform their duties. Like all federal agencies and military branches, the United States Air Force (USAF) acquires the necessary funding for facility procurement through a US Congress appropriated and authorized budget. Each fiscal year, USAF requests a budget specifically for its military construction (MILCON). MILCON includes all projects costing 750 thousand dollars or more (Department of the Air Force 2003). According to the Air Force Financial Management and Comptroller, the MILCON budget for fiscal year 2011 alone totals 1.3 billion dollars. Figure 1 shows the annual MILCON budgets over the last 11 years.

The USAF MILCON budget from fiscal year 2000 to 2011 shows a general upward trend. Given the public source of funding, transparency and control of this money is an important matter that underscores the culture and practices of the federal facility procurement environment. In the pursuit of achieving the proper oversight, USAF hires the United States Army Corps of Engineers (USACE) to conduct the majority of the MILCON construction contracting and management services. In this way, USACE is the interface between the USAF end-user and the general contractors

performing the construction. The contract specifications and construction practices used by USACE, therefore, directly influences the delivery of USAF construction.

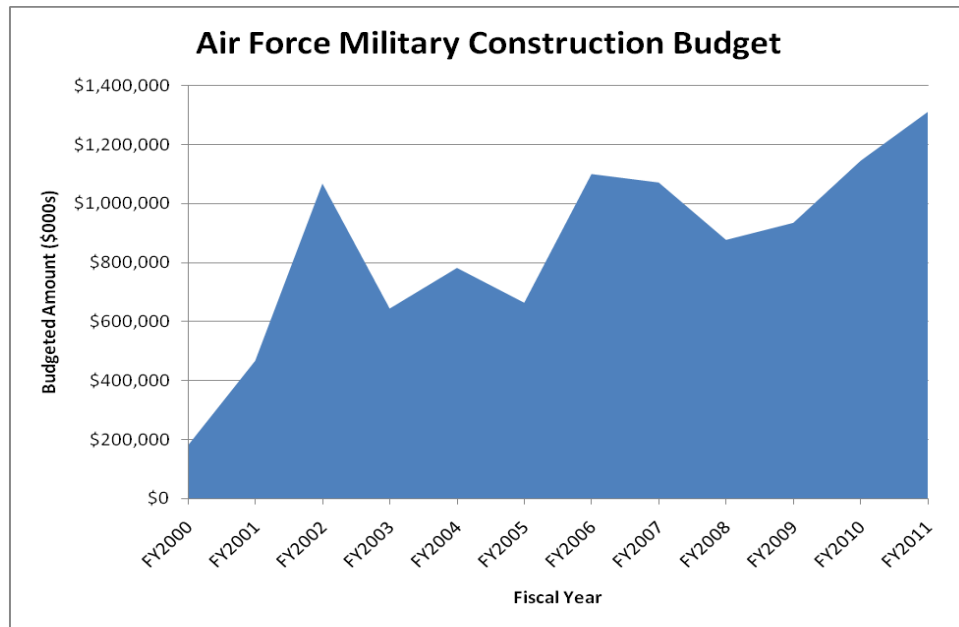


Figure 1 United States Military Construction Budget (Air Force Financial Management and Comptroller 2010)

This thesis is an inquiry into the process used in schedule communication between the USACE and general contractors working on design-build military construction on Wright-Patterson Air Force Base (WPAFB), Dayton, OH. Schedule communication is widely accepted in literature and in industry as a means to control production and monitor contract performance (Smith et al. 2009; Li and Carter 2005). Schedule specifications for the MILCON facilitated by the USACE requires submission of an initial schedule outlining the entire performance period within 42 calendar days after the notice to proceed. However, schedule forecasting for unknown work particularly in design-build projects is problematic.

Problem Statement

Schedule communication for design-build construction demands unique work structuring and execution. The USACE design-build project schedule specifications are the same used in the design-bid-build contracts. While schedules can serve as sources of contract documentation, the main intent is as a measure for production control and forecasting. However, changes during the performance period disturb the forecasting reliability. As such, initial schedules do not provide suitable baselines throughout a project life.

Research Questions

The objective of this thesis 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 versus the subsequent schedule updates. These metrics illustrate the forecasting shortfalls in the activity-based scheduling currently used in public sector construction management.

The following is a list of specific questions and sub-questions used to guide this research:

- 1) Are the schedule procedures consistent?
 - 1.1: What is the process flow?
 - 1.2: How do the USACE specifications differ between projects?
 - 1.3: How do the BCC schedule submittals differ between projects?
- 2) What is the overall scheduling performance of each project?

2.1: Is the initial schedule a suitable control baseline for the remaining schedule status updates?

2.2: Does the compilation of project schedule updates display any trends in total cost, duration, and activity count?

2.3: How much change occurs before versus after design completion?

3) Does the scheduling process facilitate planning and execution of the project?

3.1: What decisions are communicated through schedule updates?

3.2: How and when are change orders and modifications captured in the schedule updating process?

3.3: Do schedule specifications align goals with incentives?

Altogether, the focus is a system examination of the process in performing schedule updates. Question 1 and the sub-questions elicit a comparison of processes between projects with respect to the specifications and observed practices. Question 2 and the sub-questions prompt an appraisal of the cost, duration, and activity count metrics from the schedule updates to understand forecasting performance. Question 2 incorporates timing of the measured changes in the assessment as well. Finally, question 3 and the sub-questions probes the overall management aspects observed in the schedule update development.

Scope and Approach

This research seeks to evaluate schedule data collected from three design-build MILCON projects on Wright-Patterson Air Force Base (WPAFB). The projects all take

place on Area B on WPAFB as seen on the map in Appendix A. Following are the case study projects:

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

Comparative analysis on the variance between the approved initial schedules and the corresponding periodic schedule updates throughout the contracted period provides the quantitative assessment of the research.

The qualitative methods in this research involve process mapping and root-cause analysis to examine the schedule management practices. Process mapping reveals the overall and monthly schedule update process and communication flow between the general contractor managers and USACE managers. The contract requirements and current information systems direct most of the exchange and organization of the schedule data. However, the human interactions influence how the process operates as well. In this way, the qualitative assessment of the procedure helps identify the nuances and behavioral elements present in updating the schedule.

Significance

The use of schedule specifications is present in all federal design-build facility procurements. Understanding how these specifications influence management practices

and the pursuit of project control can affect the overall project performance. This research may help identify shortfalls in activity-based scheduling applied throughout the construction industry and distinguish a need for more reliable schedule forecasting practice of projects.

Preview

This thesis uses the scholarly article format. The following chapter is the article produced from the research, which was submitted to the 2011 *Lean Construction Journal*. The article provides the body of this thesis and contains all the elements of research in its layout as prescribed by the peer review journal. As an independent chapter, it includes an abstract, introduction, literature review, objective, limitations, project descriptions, research question and methods, analysis and results, recommendation, and conclusions. Chapter 3 offers a final discussion of the article conclusions along with pertinent findings and future research not discussed in Chapter 2.

II. Scholarly Article

Submitted to Lean Construction Journal 2011 (www.leanconstructionjournal.org)

Schedule Forecasting Shortfalls in Federal Design-Build Facility Procurement

Timothy Gannon, Peter Feng, William Sitzabee

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 will help identify shortfalls 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 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 the mandated transparency and equity. This pressures the 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). 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, Shen, and Ren 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 inherit 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 obligate funds and maximize budget execution. As such, schedule communication remains a critical management process.

In further exploration of the scheduling dynamics, 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. This type of activity-based tracking, however, is not the only option for conducting scheduling operations.

Though not explicitly used in the observed projects, 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 particulate, the Last PlannerTM 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 the following four levels of planning:

- Master scheduling: sets phase milestones, special benchmarks, and long lead items
- Phase scheduling: uses collaborative planning to detail phase activities backwards from the milestones and determines handoffs and resources
- Lookahead planning: spans a horizon of two to six weeks into the future and makes work ready by removing constraints and identifying responsibility
- Commitment planning (weekly work plans): designate assignments, measure percent plan complete (PPC), identify failure root causes, and learn

Using these four levels of 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 baseline for measured progress is a current set of promises or goals. Although our three research projects do not use this system, the Last PlannerTM provides an alternative scheduling method applicable to future discussion of the public sector.

Following a review of the objective and limitations, this paper has a short summary on the project descriptions. 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 briefly 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 versus 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. Coincidentally, 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 experiment 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 involves multiple handoffs using redundant information systems. The value stream mapping (discussed more in Chapter 3) 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.

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)			
Total % Duration Growth ((Last scheduled total duration – original duration)/original duration)*100%	540 29%	570 10%	690 7%
Initial Number of Activities			
Total % Activity Growth ((Last scheduled activity count – original activity count)/original activity count)*100%	331 31%	544 31%	1084 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

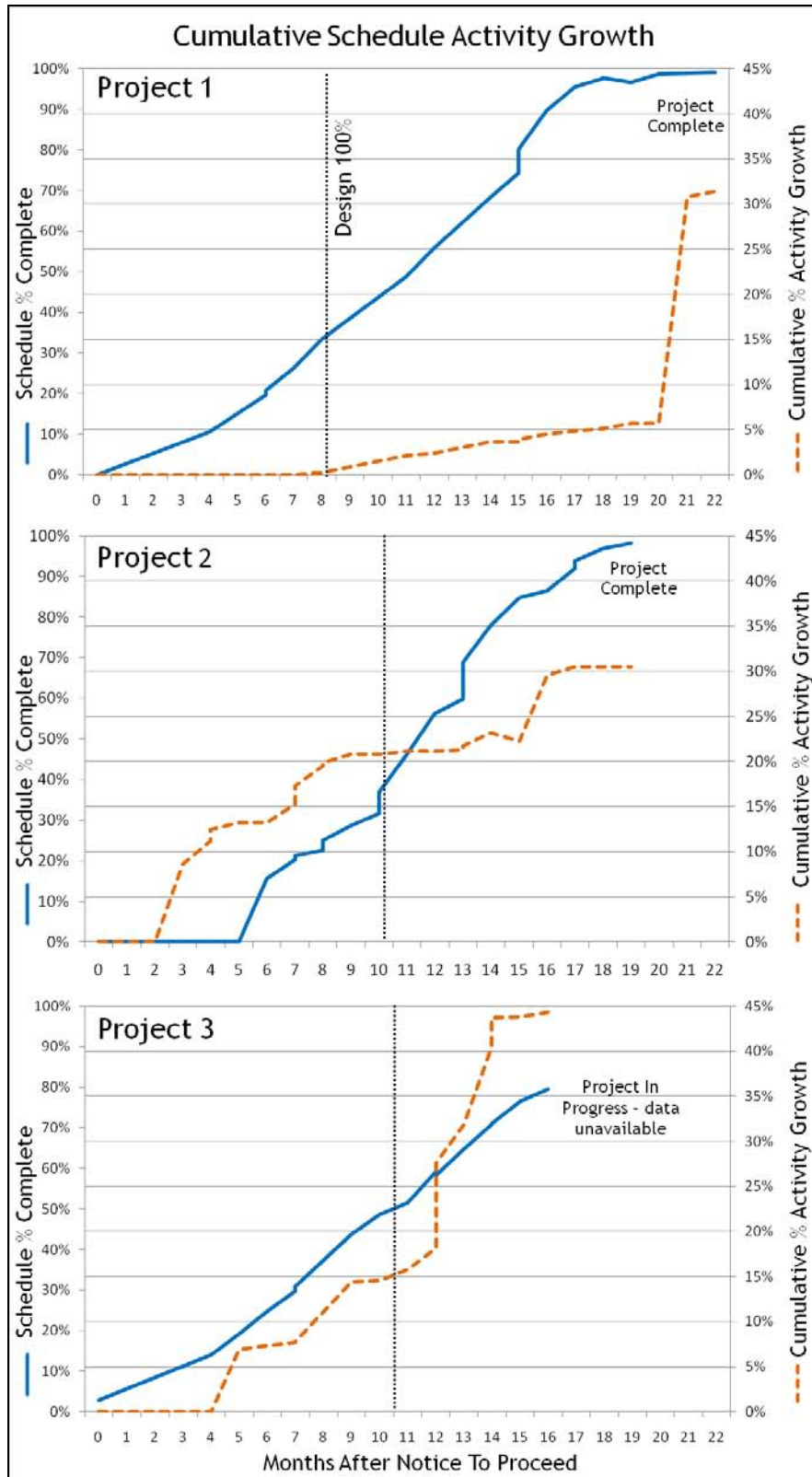


Figure 2: Cumulative Schedule Activity Growth

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 specification to establish a single baseline 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 schedules appear dynamic in the attempt to capture unexpected modifications throughout the performance period.

Recommendation

Given the unintended schedule dynamics, our recommendation is to establish a phased schedule requirement for federal facility procurement to align with design approval milestones. As seen in the cone of uncertainty in Figure 2 below, the variability early in a DB project at 35% design is much greater than later at 100% design.

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. However, as more design is completed, the cone narrows shaping a reduction in the level

of project uncertainty. The timing in which a baseline is established determines the amount of uncertainty the schedule will carry and potential for rework in activity execution. Moreover, 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.

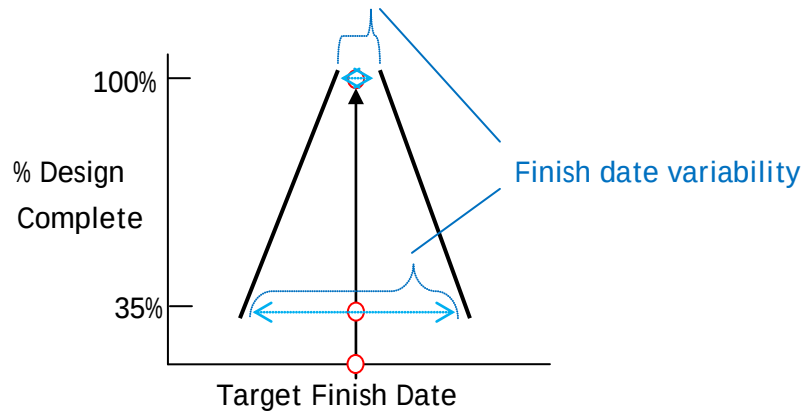


Figure 3: Cone of Uncertainty

Using this concept, the GC could submit schedules following design approvals at 65%, 95%, and 100% and develop a progressive baseline 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.

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 can 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. Since the unknowns for DB projects are unavoidable, the four-tiered planning approach of the Last PlannerTM system may provide a 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.

Bibliography

The references of this article are combined with the thesis following appendixes.

III. Conclusion

Chapter Overview

This chapter discusses the research findings in relation to the original questions outlined in Chapter 1. The scholarly article submitted to the 2011 *Lean Construction Journal* communicates all the prominent results of the research. However, due to particular constraints in the manuscript length and formatting standards, the article does not include a portion of results discussion as well as the visual maps referenced as appendixes in the thesis. This chapter first briefly reviews the findings with respect to the questions that generated the research. The significance of the research is then discussed. Finally, future research and a summary of the thesis form the concluding portion of the thesis.

Review of Findings

The three research questions presented in the introduction inquire about 1) the consistency of project schedule updating procedures between the projects, 2) the scheduling performance based on the metrics, and 3) the facilitation of overall management in the projects in relation to the scheduling process. The sub-questions presented along with the question areas help detail how to address each of these inquiries. Accordingly, the discussion below provides a complete review of the findings in the context to the research questions.

1) Scheduling procedure findings:

Using the tool of value stream mapping presented in Rother and Shook's guide *Learning to See* (1998), the process flows of the USAF MILCON schedule formation and

the monthly schedule updating process were created to visually characterize how the processes work (see Appendix B and Appendix C). These value stream maps identify that the process flow involves multiple hand-offs with redundant information systems. For example, the USAF MILCON schedule formation map reveals a communication interface called QCS/RMS between USACE and the GC. In order for the GC to transfer the updated schedule data to USACE, they must make an input into QCS, which then ties into RMS. On a more detailed level, the monthly updating process involves an information exchange fragmented by different USACE personnel reviewing different elements of the schedule. The percent schedule complete and percent duration complete are different flows of value that eventually funnel to the USACE project manager. Even though the schedule information flow involves some duplication of efforts, the process is standardized and guided by nearly identical schedule specifications for all projects. Overall, differences in project scope, budget, and personnel are handled with uniform and perhaps less than efficient schedule procedures.

2) Scheduling performance findings:

The initial schedules fail to capture all costs, durations, and activities present later in the project. That is, projects do not remain conformed to an initial baseline. Changes to the project scope are the main cause of the overall growth in all the metrics. Interestingly, achieving 100% design does not reduce the rate at which the growth occurs. In fact, a majority of the schedule variability occurs after the design phase is complete. Each of the projects show that late change underscores the evidence of poor schedule forecasting. Unless final scope decisions are made earlier in the project, the schedule will require substantial revisions.

3) Management findings:

Schedules provide the basis for many management decisions including progress payout, resourcing, material acquisition, and project control. The schedule data communicates a networked system of work and provides justification for the timing of work. In this way, the schedule tool facilitates discussion for managers. However, the schedule updating process for these projects was observed as reactive progress reporting verses proactive planning and execution. Furthermore, GCs struggled to consistently incorporate change orders given a delay in the government approval process. The misaligned schedule utility and goals perceived by USACE and the GC also generated friction. Altogether, scheduling falls short of providing a comprehensive planning and executing tool for all stakeholders. Instead, each management level uses portions of the construction schedule process to verify discrete budget and duration checks.

Significance of Research

As federal agencies procure forthcoming facilities, the construction management processes and practices that guide the work will continue to impact delivery and future operations. Scheduling is a key management tool that provides work structuring and control during a project, which translates into functional products for the end-user. This inquiry into the USACE scheduling specifications and process highlights shortfalls that need to be addressed. The uncertainty present early in design-build construction requires attention. Accordingly, this research identifies how the current USACE contracting rules for schedule updates do not enable contractors the flexibility to quickly address deviations from the baseline schedule. As seen in the variability of cost, duration, and

activity count in the schedule updates, change is the recurrent culprit however. The impact of this finding extends to all federal facility procurement programs and the construction industry as a whole. Since scheduling practices provide a foundation for work communication, ensuring reliable forecasting in the midst of uncertainty is an ongoing challenge for all construction managers.

Future Research

This study touches on several facets within federal facility procurement not addressed in the scope of the thesis. These facets offer opportunities for future research. The general topics are as follows:

- Change order process (submitting and approving)
- Impact of modifications (controllable verses uncontrollable)
- Validation of schedule performance metrics
- Schedule performance comparison of DB vs. DBB
- Development and demands of scheduling expertise (scheduling experience and training of USACE and GC managers)
- Productivity tracking on schedule (resourcing analysis)
- Schedules beyond construction (ongoing commissioning activities)

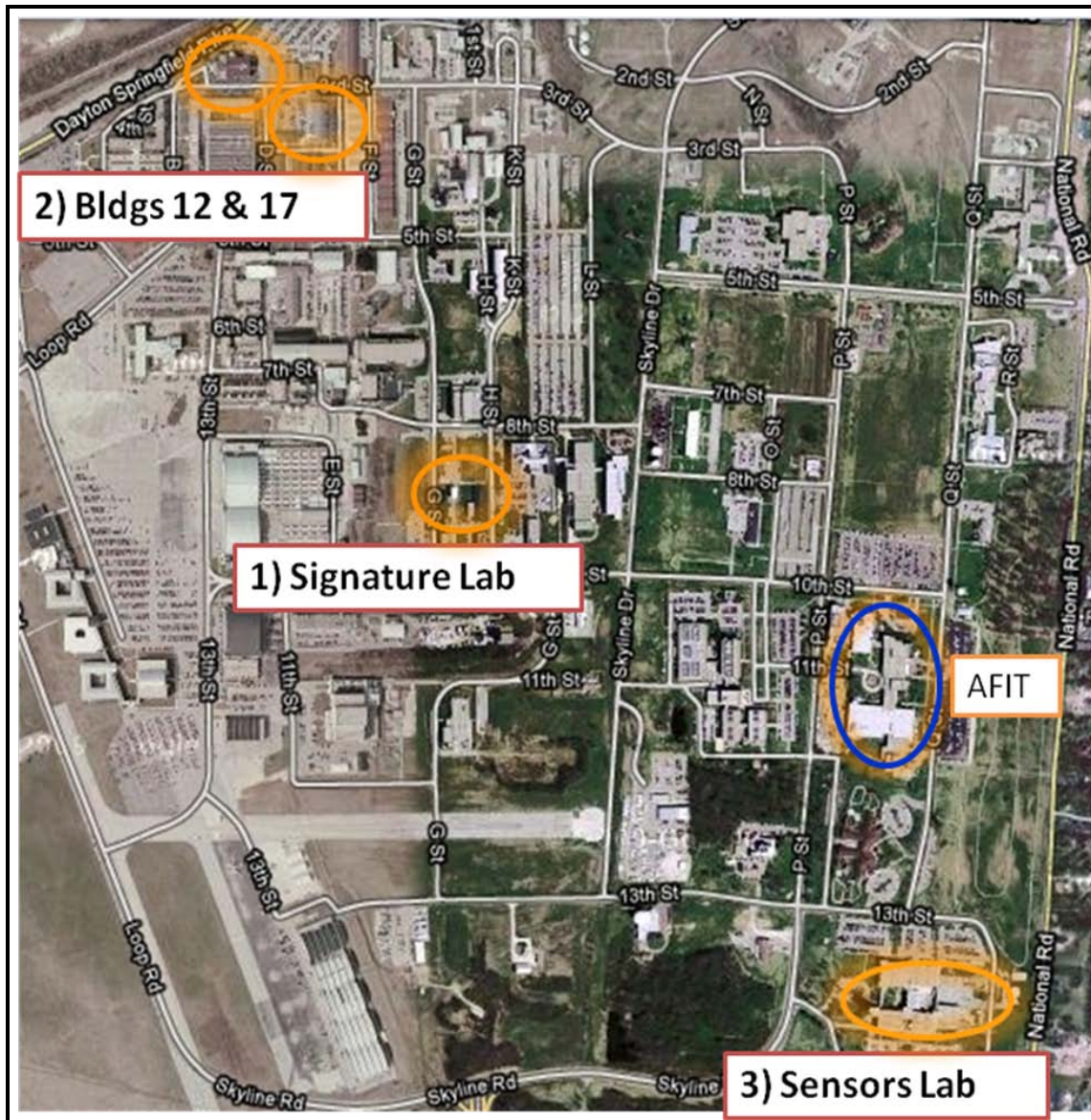
The efforts of this research focus on identifying the growth of cost, duration, and activities in the schedule updates. However, the root cause analysis points to the modifications and process of incorporating change as the underlying problem. Further research into the expected impacts of modifications as well as a validation of metrics for schedule performance would offer insight into implementing improvements. Other topics

concerning scheduling and management, including the comparison of contract delivery systems and the development of scheduling expertise, could provide a better understanding of impacts to construction management. Finally, resource analysis and commissioning endeavors are related subjects that are important to the execution of scheduled work and the ongoing management of facility procurement, respectively.

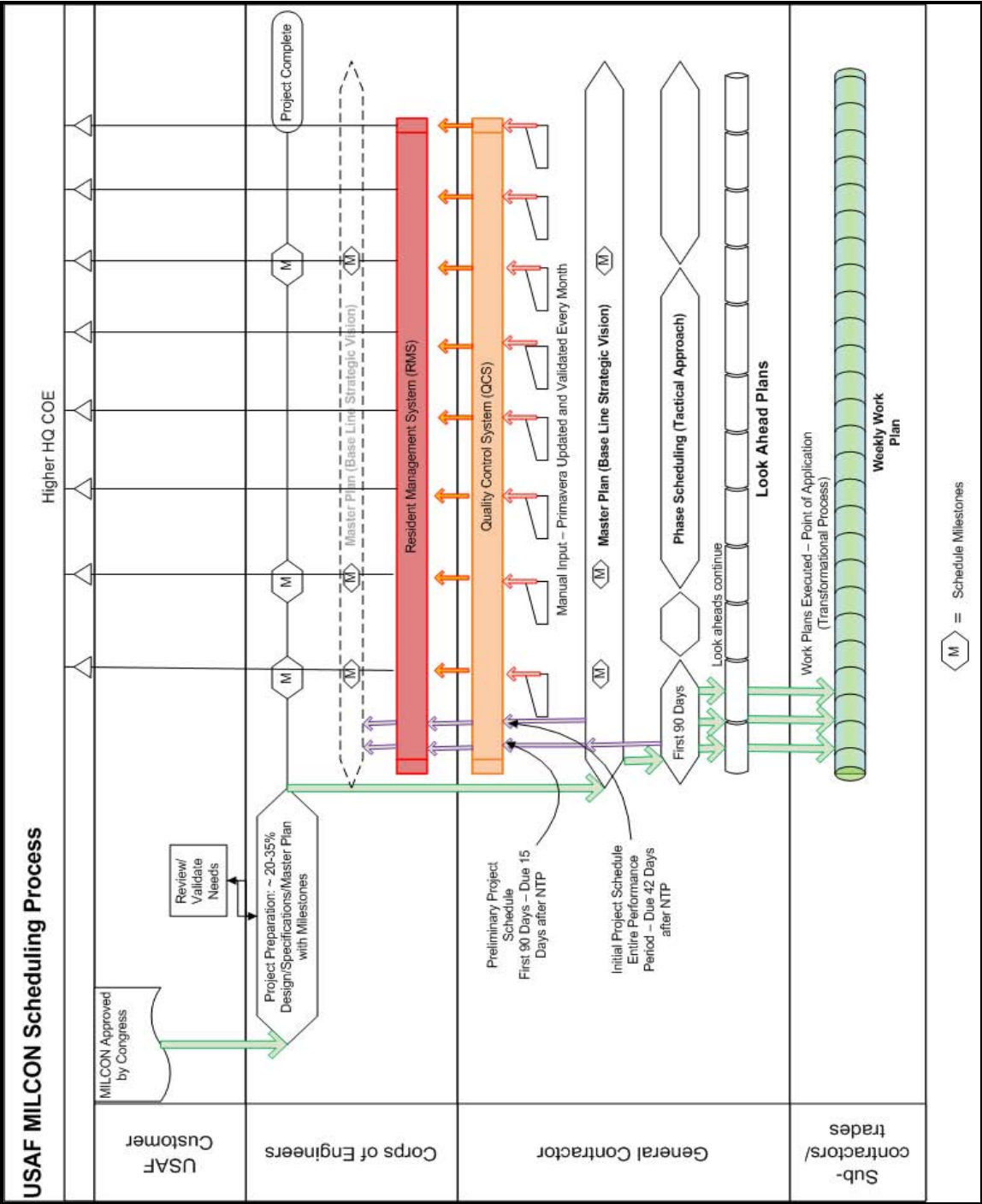
Summary

This research explored whether initial schedules provide reliable forecasting for project control in federal design-build facility procurement. The purpose of this research was to understand how scheduling operates in the Department of Defense environment and identify how project change underscores schedule uncertainty. The research methodology involved a comparative analysis of project schedule data from three case studies. The investigation 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. Furthermore, activity growth highlights the day-to-day scheduling challenges encountered by the construction managers and general contractors. The research was limited to three military construction projects managed by the United States Army Corps of Engineers (USACE) on Wright-Patterson Air Force Base, Ohio. Future implications resulting from the research include a call for reexamination of federal design-build schedule specifications and management practices in the pursuit of project control. Overall, the schedule analysis identifies shortfalls in activity-based scheduling and promotes an application of lean thinking in public sector construction management.

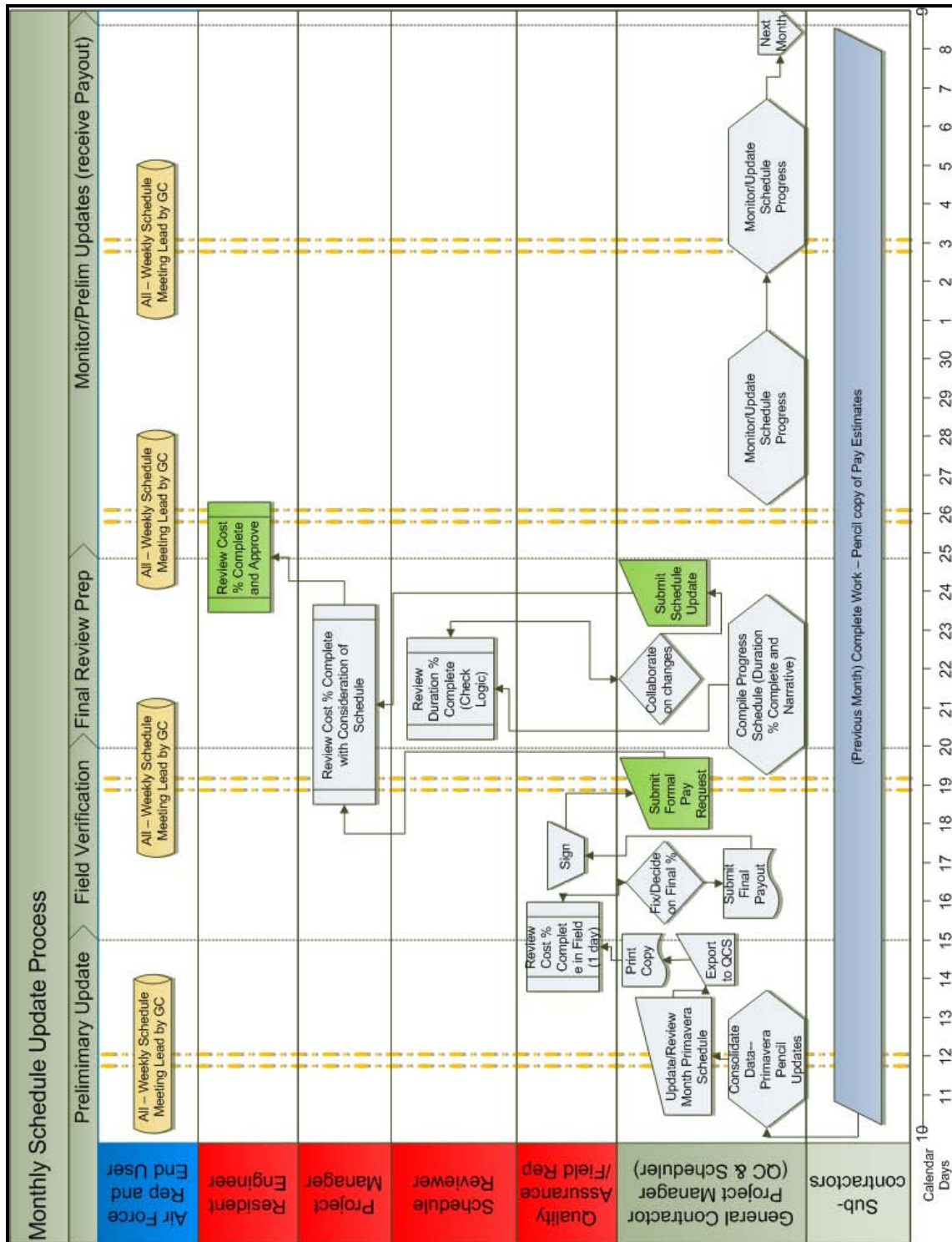
Appendix A. Map of Researched Projects on WPAFB Area B



Appendix B. Value Stream Map of USAF MILCON Schedule Formation



Appendix C. Value Stream Map of Monthly Schedule Updating Process



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Vita

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