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Informing DoD Program Planning Through the Examination of the Causes of Delays in Acquisition Using Acquisition Data

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Abstract

This research has two objectives. First, using DoD acquisition data, the study details the process developed to mine, convert, and use DoD acquisition schedule data, including a discussion on how the data was refined. Part of this effort was an identification of the factors that caused delays. This data is used to describe a method for project managers to use in their project planning process.

Introduction

Department of Defense (DoD) project management is focused on awareness, anticipation, and decision-making. In order to address these three imperatives, project and program managers in the DoD must plan in detail the expected path and duration of development projects as senior leadership requires reports on progress relative to a plan. However, since the nature of the weapons development process (R&D) is so uncertain and the scheduling tools provided are, at best, stochastic, there is a need for better understanding of the many factors that influence activity/task planning, network development and project execution. This understanding includes ways to estimate schedule beyond the stochastic methods of today. This research has two objectives. First, using the OSD acquisition information databases, determine and develop ways to extract and make that information on scheduling available to DoD project managers. The second goal is to identify important delay factors, so those factors can be considered in project planning.

This research uses DoD acquisition data to inform the schedule planning process. Specifically, it identifies the many factors that have historically led to schedule delays and provides a methodology for PMOs to use when they plan and schedule their weapons system program. This study has three parts. First is an examination of the literature on the current state of schedule estimating. The second part describes the process developed for this study to mine, convert, and use DoD acquisition data, including a discussion on how the data was refined. The last section presents some initial findings from this research and proposes some uses for the information.

The widely used definition of a project includes the assumption that each project is something unique: "[a] project is a temporary endeavor undertaken to create a unique product, service or result" (Project Management Institute [PMI], 2017). Perhaps it is not. Instead, perhaps a project is not unique, and perhaps we can use the experience the DoD has in project management to our benefit. That is the value of using data in defense acquisition.

As long ago as 1988, Morris and Hough were critical of the practice of project management:

> Curiously, despite the enormous attention project management and analysis have received over the years, the track record of projects is fundamentally poor, particularly for the larger and more difficult ones. Overruns are common. Many projects appear as failures, particularly in the public view. Projects are often completed late or over budget, do not perform in the way expected, involve severe strain on participating institutions or are cancelled prior to their completion after the expenditure of considerable sums of money. (Morris & Hough, 1988)

Instead, the basic premise of this study is to address this criticism head-on and suggest instead, that maybe … when problems persist, practitioners and scholars are getting something wrong (Christensen & Bartman, 2016). Therefore, this study explores how to find and use data to help PMs understand the dynamic nature of weapon system development.

Managing defense acquisition schedules has become even more important in recent years for many reasons including the following:

- Longer “cycle times” for defense acquisition programs, especially for high-priority combat systems—in both absolute and relative terms
- The rise of competitor nations with greatly increased capabilities, sophistication, and agility—threatening U.S. national interests (getting inside our development cycle)
- Significantly limited resources available for defense modernization programs, which makes management of funding profiles especially important

This research explores one of the available sources of acquisition data, the Selected Acquisition Report (SAR). SAR data is collected and stored in the Defense Acquisition Management Information Retrieval (DAMIR) database, a repository for, *inter alia*, the DoD Selected Acquisition Reports (SAR). The SAR is a summary of the acquisition data of selected Major Defense Acquisition Programs (MDAP). SARs are required by Title 10 USC § 2432 to be submitted to Congress periodically.

Weapons system development projects are infamous for exceeding time and cost constraints. Study of this time phenomena however, generally focuses on the resultant time it takes to develop a weapon system, not the front-end planning necessary to address schedule overruns. We examine this topic first by reviewing the basics of project scheduling, then examining the project planning process and how scheduling is currently done, what is considered in the development of project schedules, as well as what should be considered.

Project Scheduling

The concept of time in project management can be divided into two major categories: task duration estimation, and task sequencing and project scheduling. First, the technical process of estimating the duration of the project task must be determined. Once duration is established, the management process of project sequencing and scheduling must be defined.

Broad review of the literature on project scheduling reveals research roughly divided into three areas. First, the bulk of literature on scheduling is devoted to the networking and probabilistic techniques which have dominated schedule estimation since the 1960s. This focus is logical in that the “science” of scheduling originated with the almost simultaneous development of the critical path method (CPM), and the Program Evaluation and Review Technique (PERT). CPM or critical path method places activities in a logical network sequence. When completed, this sequence is expressed as a network and provides the total time necessary to accomplish the project, as well as the total time of the individual activities which is expressed as the critical path. PERT also used in building the network provides a probabilistic assessment of the actual schedule time. PERT (also known as three-point estimation) uses the weighted average of three measures of task duration, the most likely duration (M), the pessimistic duration (P), and the optimistic duration (O).

The strength of CPM and PERT (apart from the fact they are used almost exclusively in schedule development, and in most enterprise project management software packages) is it allows management focus by identifying the critical path, thus, the key activities that must be monitored and controlled. Monitoring provides a means to oversee costs including, among others, anticipating personnel changes. Controlling allows the PM to determine whether the project is on schedule, as well as ensuring the defined length of the project is met.

Disadvantages include project management being unable to react to instability and changes, as well as managing resources to “feed” the critical path and not being able to “see” and comprehend the overall effort. This is because CPM and PERT take a static view of project activities—which fails to account for the relationships and interdependencies inherent in complex projects (Balaji & James, 2005).

Second is the basic assumption that work proceeds as planned in the network—that there is a direct flow from work to be done, to work accomplished. That is, every task has a discrete start and end—work is either started or not, finished or not. More importantly, there is no accommodation for work that might not be done correctly or to the required quality. Further, the subjective nature of defining not only the most likely time duration, but also the optimistic and pessimistic durations potentially magnifies schedule uncertainty especially in large, complex projects (Franck et al., 2017). A last disadvantage of the current scheduling method is that it does not recognize management decisions and the feedback from those decisions.

The next major area in the schedule literature examines project schedule from the perspective of the time it takes to develop weapons systems. This research focus assesses schedules by asking the question, “Why does weapon system development take so long?” Central to this line of research is the idea of “cycle time,” also referred to as “schedule interval.” The issue examined is how to provide weapons systems to the operational force as soon as possible. Research questions ask, “Has the time to develop weapons systems increased?” (Van Atta et al., 2015).

The final area of research interest is that of software project estimation. This area represents the focus of the most recent research. Some suggest that because of the complexity of software, as well as the degree of software in most modern weapons systems, software schedule estimation most closely resembles weapons system development scheduling.

Estimating Activity Duration

Surprisingly, little information is available in the literature on the "how" to estimate the measures of a schedule—the task duration. While the major defense contractors have formal in-company processes, little formal literature is available on the specifics of task estimation. Further, most available information on estimating task duration is found in project management textbooks, but even then, the specifics are scarce.

There are however, similarities between cost estimating and activity duration estimating. This is because accurate cost estimates require the insight into scope and schedule that only duration estimating can provide. Both processes use similar techniques. Both depend on expert judgment, both use parametric methods, and both employ a bottoms-up methodology as one of the techniques is estimated at the task level, then rolled up. Central, however, to schedule estimation is the idea of sequencing. The network is a central element of determining duration.

The PMBOK (Project Management Body of Knowledge) lists five methods for estimating project activity duration. These methods include the following (PMI, 2017):

- Expert Judgment
- Alternatives Analysis
- Published Estimating Data
- Project Management Software
- Bottoms-Up Estimating

Expert judgment acknowledges that technical and engineering experts should be able to estimate the effort necessary to accomplish tasks and translate those estimates to duration. This assumes the chosen experts have significant experience in the execution of those tasks and are therefore competent to judge time required (Hughes, 1996).

Alternatives analysis recognizes that activities or tasks can be accomplished in different ways—alternatives. These different ways include defining different techniques, differing levels of resources, and using different machines.

Published estimates are databanks that gather resources measures. These measures include hourly rates by skill level, acknowledged production rates for various development and manufacturing activities. In most cases, this data is available internal to the organization. However, there are data companies that track and report this data. An example is the IEEE-USA Salary & Benefits Survey. This data is often available for different locations in the United States, as well as worldwide.

Project management software is not really an estimation method. Instead, it provides a means to identify and organize information necessary for resource estimates.

Finally, an engineering or bottoms-up estimate is a comprehensive schedule (and cost) process that starts at the work package level and aggregates costs to build a complete estimate. Bottoms-up estimates are necessary when schedule activities cannot be accurately estimated using another technique. As the name implies, bottoms-up estimates start at a level of activity or task that can be confidently estimated. The activities are then rolled-up to the required level. These estimates are extremely work-intensive but are also the most accurate.

Other recognized methods include parametric techniques. A parametric or top-down estimate builds an activity estimate for the development project from historical data comparing variables through a statistical relationship. All the methods listed are used to estimate the length of time each of the activities or Work Breakdown Structure tasks lists. “Simply stated, the duration of an activity is the scope of the work (quantity) divided by a measure of productivity” (Hendrickson et al., 1987, p. 278).

Thus, activity duration estimation establishes the actual time required to complete discrete tasks in an overall project, while project scheduling fixes the start and end dates, as well as execution approaches of the project. Once the overall schedule is established, management activities driven by either time or resource constraints will determine the actual execution of the project (Schwindt & Zimmerman, 2015). The analogy that comes to mind is that of an orchestra. The individual instruments (and of course, the musicians) are the discrete tasks of the project. The orchestra leader is the project manager, and the music score is the “plan” the orchestra leader uses to execute the “project.” Building on this information, the next step in this effort is to identify schedule data that can be used to augment these estimating activities.

Data Methodology

While there is significant information available on DoD procurements, the overwhelming majority of that information is on cost. Cost is tracked and reported in detail at both the service as well as DoD level, and there is significant numerical-type data available on cost. Cost is also reported in a format that lends itself to analysis (spreadsheets). In fact, both in government and industry, cost is significantly more frequently reviewed than schedule (Smith & Friedman, 1980).

Schedule information, on the other hand, is reported by DoD program managers, but normally in prose or tables in reports such as the SARs and others. The challenge for this effort was to identify schedule data and render it into a form that can be mathematically compared and examined. This section discusses the process developed to convert schedule information into schedule data.

Data for this research was obtained from the Defense Acquisition Management Information Retrieval (DAMIR) database, a repository for, *inter alia*, the DoD Selected Acquisition Reports (SAR). The SAR is a summary of the acquisition data of selected Major Defense Acquisition Programs (MDAP). SARs are required by Title 10 USC § 2432 which states,

> The Secretary of Defense shall submit to Congress at the end of each fiscal-year quarter a report on current major defense acquisition programs. Except as provided in paragraphs (2) and (3), each such report shall include a status report on each defense acquisition program that at the end of such quarter is a major defense acquisition program. Reports under this section shall be known as Selected Acquisition Reports.

The available DAMIR database includes SARs from 1997 to 2017. The schedule section of the report consists of a Gantt chart and table showing the major milestones and current estimates. Figure 1 is an example of the schedule data found in a SAR. The section titled Change Explanations (CE) provides a description of the schedule changes. Both the graphic and the change explanation sections are rendered as unformatted text.

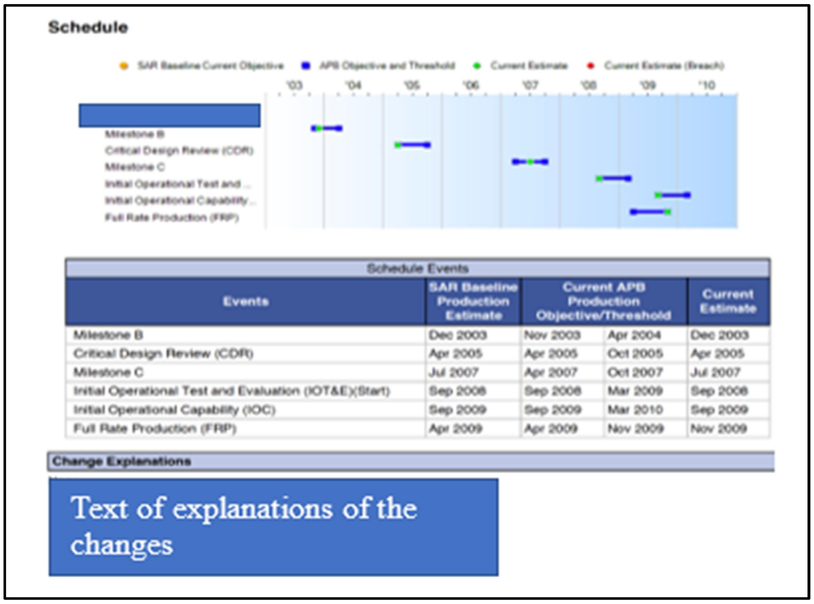

Figure 1. SAR Schedule of Data Example

The information reported by the program managers in the SAR consists of an executive summary, a brief description of the overall program with separate sections for major subprograms and identification of threshold breaches and discussions on cost, schedule, and/or performance issues. The database can be searched by program and year. Data accessibility work by OSD now provides the possibility of extracting SAR data from PDF forms into a spreadsheet. Specific queries allow an analyst to mine particular sections of the SAR, to include that used for this effort—schedule. The extracted data for schedule includes program information, key dates (milestones) and other identifying information. However, the data describing what changed and by how much is provided as text. Thus, a process needed to be developed to convert textual explanations to normalized, measurable data.

The total number of schedule records in the available SAR database was 3,969. The data used in this study are a subset of the SAR reports of 1,224 programs from 1997 to 2017. Each program potentially had between one and 20 entries (corresponding to the 20-years period and depending on when the program was initiated, and whether any schedule changes were reported). Of those 1224 programs, the available SAR schedule data consisted of 1,948 entries in the “change explanation” (CE) field of the database. In this preliminary study, those systems with no entries in the CE field were not examined. Table 1 details the overall data.

Table 1. Overall SAR Data Information, 1997–2017

Time period covered	1997–2017
Total number of records in the obtained data	3,969
Total number of programs in the database	1,224
Number of Programs/ Subprograms with Schedule Change Explanations	165
Total number of change explanations	1,994

Central to an understanding of weapon system scheduling (and as a way of converting change explanation text to data) is an examination of those factors that historically have led to increases in weapon system development times. The major studies of the past two decades have identified a number of factors that have contributed to increased duration. Thus, the next step was to identify these factors. A literature review revealed several studies that have classified weapon system development delay factors. An example of the explanations includes budget, funding, complexity, technical difficulty, and requirements stability (Drezner & Smith, 1990; Smith & Friedman, 1980; Van Atta et al., 2015). A list of these project delay factors is at Table 2. Not all these previously identified delay factors were evident in this study; however these factors provided a starting point for this analysis.

Table 2. Identified Generic Factors Causing Delays in Weapons System Development

Factors
Competition at the prime contractor level
Concurrency, overlap in time and effort between the development and production phases of a program
Funding adequacy/ stability
Existence of prototyping
Separate contracts for each phase of the program
Priority of the program to the service relative to other ongoing programs
External guidance such as OSD or congressional direction, reviews, restrictions, and designations
Joint management with other agencies
Program complexity, or interactions with agencies external to the program
Technical difficulty
Concept stability, or stability in mission, operational concepts, and doctrine
Contractor performance changes/Contract changes
External events such as inflation, earthquakes, labor strikes, etc.
Major requirements stability
Program manager turnover
Rework
Design Freeze

The classification of the change explanation (CE) entries was a two-step process. First, each change explanation was examined and a determination on causality made. Using the abovementioned factors as a classification mechanism, in the first pass, the project office change explanations were examined, and an initial determination of the schedule factor(s) was identified. It became clear in this preliminary analysis that in many cases, there was more than one cause of the delay. Those explanations with more than one cause were initially classified, then further refined. Those entries that required further analysis were flagged in order to return and further refine the classification. Some data were not assigned a code because of either duplicative information, or because of what appeared to be arbitrary schedule updates that appeared to be no real changes in schedule activities. Table 3 shows the delay factors identified/determined in this analysis, and the number of identified cases of each factor. Numbers do not total because of more than one factor identified on some of the programs.

Table 3. Minimum and Maximum Schedule Delays (Months)

Delay Factor	# instances	Maximum Delay (months)	Minimum Delay (months)
Administrative changes to schedule including updates to APB, ADM changes as well as changes resulting from Nunn-McCurdy processes and program restructuring	460	168	5
Technical	291	60	4
Testing delays	283	66	1
Delay in availability of key capabilities/facilities (launch vehicle/testing facilities/IOT&E units)	3	13	6
Budget/Funding Delays	52	43	1
Delays attributed to the Contractor	50		
Delays because of Rework	16	4	1
External events such as inflation, earthquakes, labor strikes, etc. *(Force Majeure)*	4	4	1
Delays due to Contracting/Contract Negotiation/Award delays	29	27	1
Actuals (updating previously reported dates to actual occurrence)	172	13	-39

The last step in the analytical process was to record the actual reported delays. The delays were listed in the SAR as dates. That required conversion from dates into a uniform format (months). Delays ranged from one month at the low end to 168 months on the high end. The delays were tracked to the identified factors. There were 1,216 instances of increases in time, and 150 instances of decreases in time. The delay factors, minimum and maximum delays, are shown in Table 3. Note that in some cases, dates were brought forward. In this case, those dates were noted as minus (-) numbers, representing a possible decrease in the schedule. In practice, however, a decrease in schedule captured in this manner is misleading since it is taken out of the context of the overall project. Over 95% of deceases noted were administrative in nature and either were corrections to mistakes recorded in previous SARs, or a reflection of actual dates versus planned dates. For purposes of this initial analysis, decreases were not examined.

Delay Factor Explanations

- Administrative changes include schedule updates because of APB and ADM changes, as well as changes including program restructuring as a function of decisions driven by Nunn-McCurdy results and program restructuring.
- Schedule changes identified those changes reported as a result of acknowledgement of the actual date of occurrence. These changes are also the result of receipt of approval documents from Milestone Decision Authorities to change specific dates.
- Technical schedule changes are a result of specific setbacks in technical development.
- Testing delays include both the ability to meet scheduled test dates, as well as technical issues discovered in the conduct of testing. When the testing discovered a technical issue, that technical issue was also counted as a technical problem.
- Explanations that produced no apparent changes in the schedule data reflect comments in the change explanation, but do not produce an actual change in the schedule. Examples include cases of achievement of IOC/FOC, as well as re-designations of milestones driven by ADM decisions.
- Delay in availability of key capabilities/facilities are a result of weather delays including satellite launches.
- Budget/Funding Delays are tied to specific notes on lack of budget, decrease in budget or changes by Congress to the specific program.
- Delays attributed to the Contractor result from construction and delivery delays as well as delays attributed to delivery of subcontractor materials.
- Delays because of Rework reflect both quality issues where the budgeted work must be redone in order to make it functional, as well as the feedback/follow-on problems caused throughout the development.
- *Force Majeure* are external events such as inflation, earthquakes, labor strikes, etc.
- Delays due to Contracting/Contract Negotiation stem from either problems in negotiation, delays in approvals for RFP releases, modification to contracts, or delays in awarding contracts.
- Actuals are the language used to describe simple updates to previously reported dates.

The CE section included the table described above; however the information was unformatted. In some cases, numerous dates for different events had changed and were reported. For purposes of this initial research effort, the date captured was the longest duration activity shown. Future efforts will identify and report all events.

Analysis

One of the objectives of this research was to identify, analyze, and provide those schedule factors causing delays in weapons system development. The final aspect of this study is to explore how the data extracted from this SAR analysis can be used to assist in schedule planning and development. The tools of scheduling (currently based on the CPM and PERT techniques discussed above) apply a network approach to define critical activities, slack, and the overall time required to complete the development. The network approach also provides the basis for cost estimation, resource allocation, management focus and risk assessment, and provides a visual flow of the effort. However, notwithstanding decades of study and countless man-years of experience, we are still missing something. One of those things we are missing is an acknowledgement of the dynamic nature of projects. Our current static view starting with planning has to change. A first step is to review the delay factors evident in the past 20 years of DoD Major Defense Acquisition Programs (MDAP). As a minimum, incorporating factors identified in both the planning and execution process could be a start.

The delay factors suggest PMs should attempt to plan for the time necessary to deal with oversight, information reporting and both the time takes, as well as the impacts of decisions—internal and external to the program. As the GAO pointed out in a 2015 study, the program office overheads associated with administrative activities added on an average of two years to complete:

> Programs we surveyed spent on average over 2 years completing the steps necessary to document up to 49 information requirements for their most recent acquisition milestone. This includes the time for the program office to develop the documentation and for various stakeholders to review and approve the documentation. (GAO, 2015)

For example, the GAO found that the F-22 Increment $3.2 billion Modernization spent 3,800 staff days to prepare 33 milestone documents and present 74 briefings for the Milestone B process (GAO, 2015). This work had a cost of some $10 million. Those 3,800 staff days obviously would also have impacts on the schedule, potentially more significant than on cost. This is not to argue the necessity for the program office to gather this information. Instead, it is a factor that should be accounted for in the program scheduling plan.

Figure 2 shows the cumulative schedule overrun hours for all programs analyzed in the period of 1997 to 2017. Of note are years 2010 and 2011 where the year-to-year increase in time is an order of magnitude larger than that any other year. This particular jump in delay was caused by the CVN-78 program.

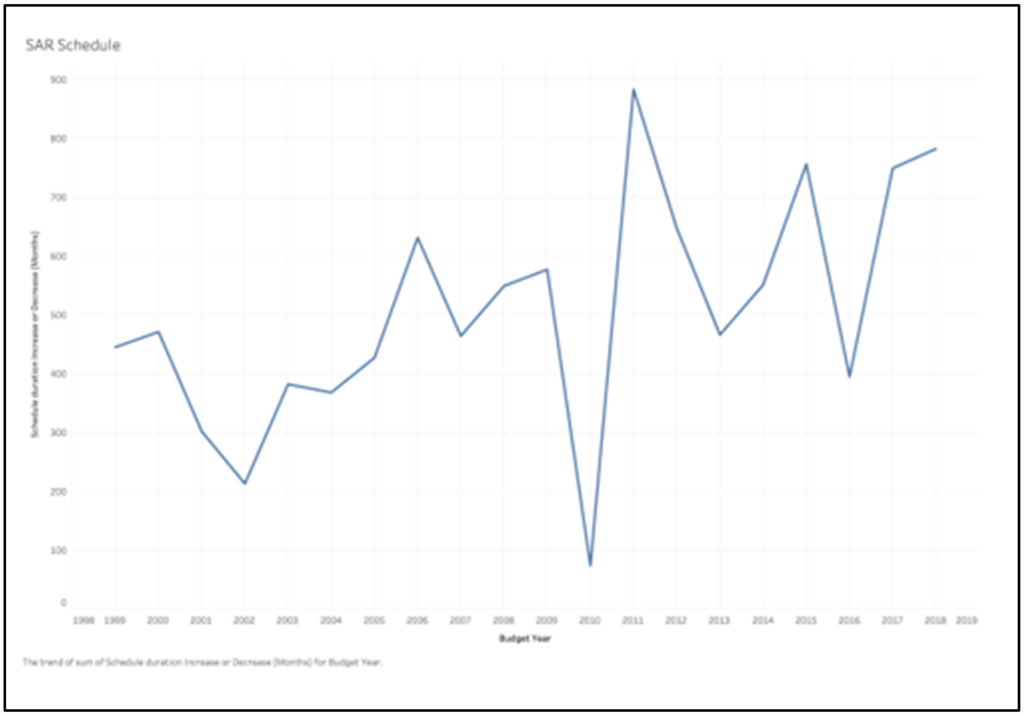

Figure 2. Sum of Schedule Delays by Year, 1998–2017

Figure 3 provides a trend line and forecast of the delay. Using this data, the forecast total delay hours across all programs in 2019 equals 712 hours, and in 2020 that forecast increases to 729 hours.

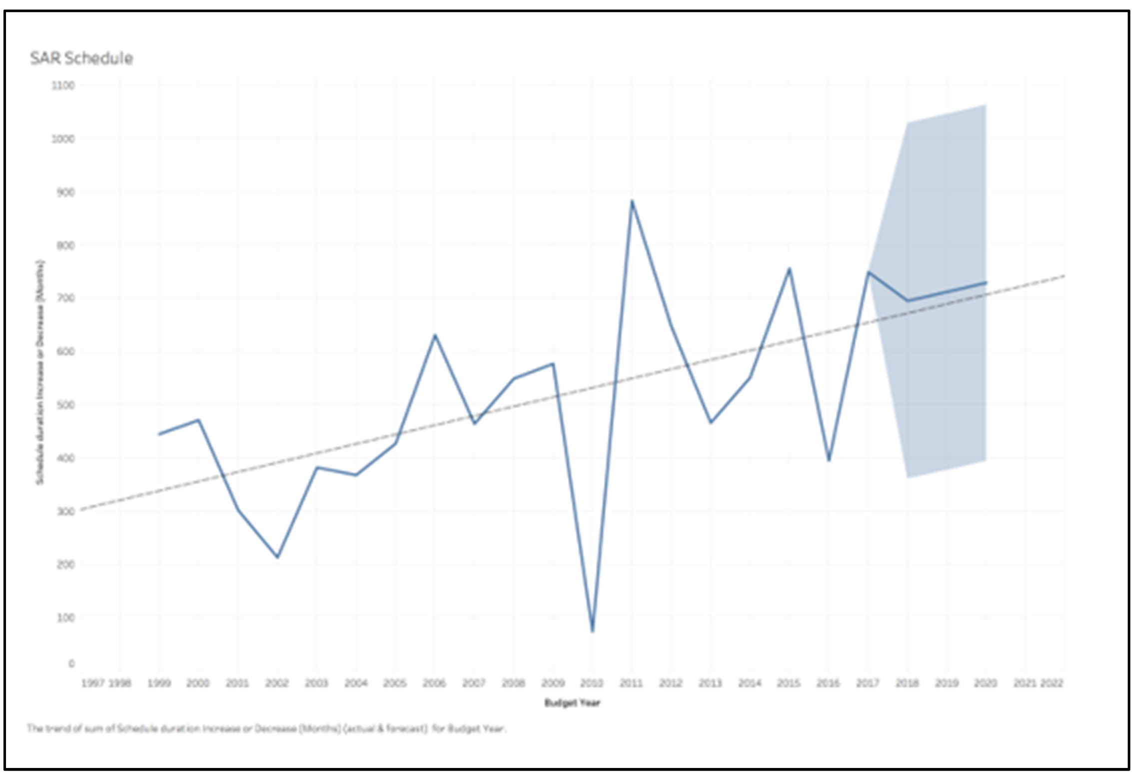

Figure 3. Forecast Total Hours for 2019 and 2020

Figure 4 shows the hours overrun by program for the same period. While there is no real proven correlation between schedule and cost overruns, the fact that the overruns are significant in this representative group of programs emphasizes the scope of the problem. And cost is not the only aspect involved. The delays also reflect added time before the systems are in the hands of the warfighters.

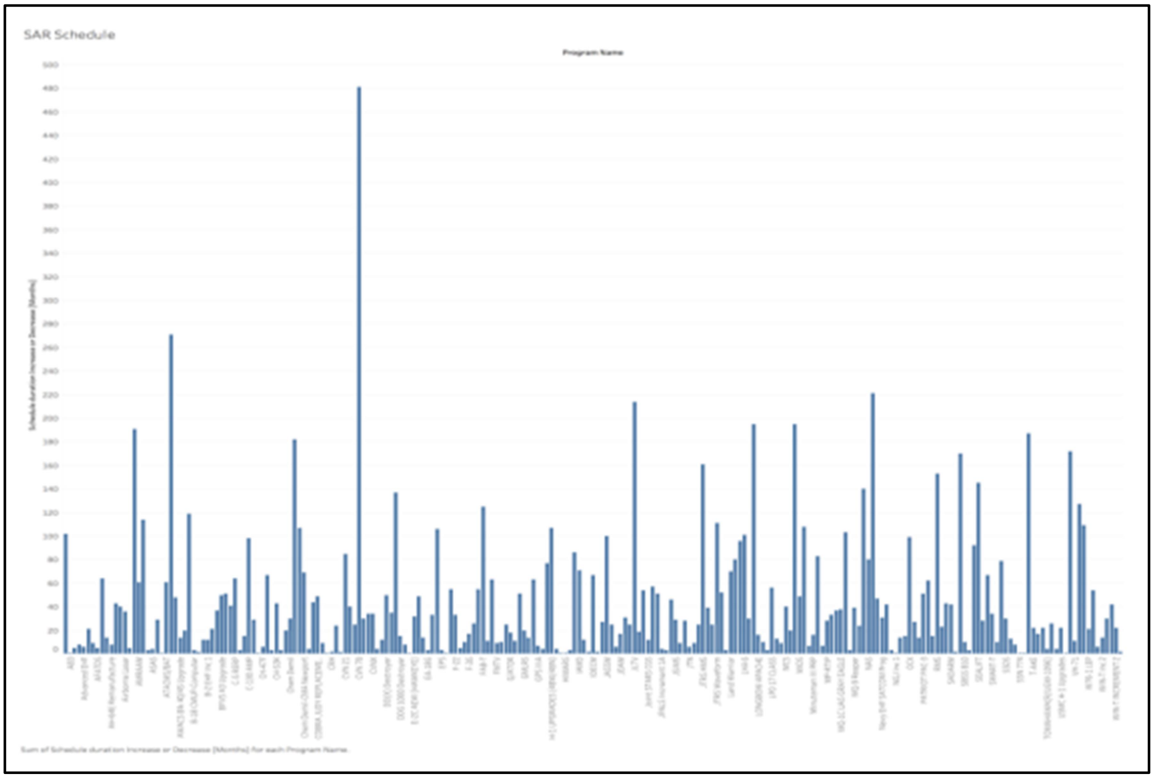

Figure 4. Total Hours Overrun by Program, 1997–2017

Using the Data

The last step in this research is to suggest a way for DoD program managers to use the data that comes from this examination of delay factors. As noted above, the CPM/ PERT approach to scheduling precludes the use of historical data at the program schedule level. And, while some companies track task estimation data, that data is often proprietary, and more focused on technical process estimation.

The basic assumption that work proceeds as planned in the network from start to finish is naïve at best (Franck et al., 2017). This static view provided by traditional project scheduling ignores the reality of project management that the work might not be done correctly or to the necessary quality (Cooper, 1993c). This same view also fails to consider that the results of decisions, whether good or bad, cause reactions in the project, much as inputs results in outputs in any system. Weapon system development reality using classical network analysis cannot delineate the progress of a project (Williams et al., 1994). Therefore, we should consider alternate ways of examining these problems.

System dynamics "deals with the time-dependent behavior of managed systems with the aim of describing the system and understanding through quantitative and qualitative models" (Coyle, 1996). Instead of the static view we are used to seeing in defense acquisition projects, system dynamics considers weapon systems development as a system, with inputs and outputs. Further, the rework cycle proposed by Cooper, also helps explain one of the project dynamics present in every development (Cooper, 1993a). Figure 5 shows the rework cycle. The concept is simple: Not all work attempted is completed correctly the first time. And, that work not completed correctly is not recognized. That work, initially undiscovered is at some point discovered and then moves into the “known rework” block. That known rework must be redone, both delaying completion of the overall project, and costing more. In practice, this effectively represents an increase in the work to be done.

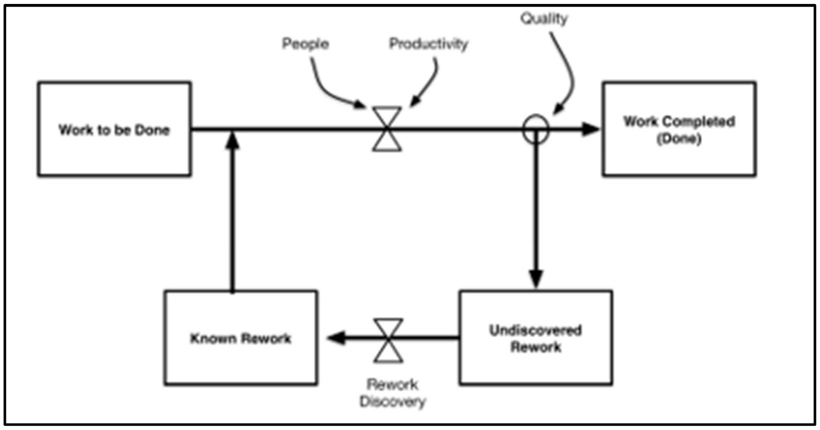

Figure 5. The Rework Cycle

The notations “people” and “productivity” flow into a valve that further controls the flow of work from that needing to be done to that work completed. People are the number of workers, and their level of training and expertise. Productivity is a measure of their efficiency. Simple scheduling in this instance takes the number of people times their efficiency and applies that to the number of tasks in the Work to be Done stock.

The rework cycle is a fundamental system dynamics concept first articulated by Cooper (Cooper, 1993a, 1993b, 1993c). The basic flow of work in a development is from work to be done (tasks or work packages) to work completed. Connecting that flow is a “valve” that regulates the flow. In the rework cycle, that flow is determined by people (numbers, skills, availability) and productivity. People times productivity provides a flow rate, for example: tasks per month. Quality is another modulator of the flow of work. Quality is simply a measure of whether the task was accomplished correctly and completely. Given the exploratory nature of research and development efforts, it is entirely possible that a planned development task fails to accomplish the task goal, and the task must be redone. Similarly, people may be operating at a high level of productivity, but not producing quality work.

There are two types of rework, known and undiscovered. These categories are integral to the nature of weapons system development. Developmental test does identify some of the work that needs to be redone, and that work flows to the known rework stock. However, there is work that may pass developmental test, but is later found to be deficient (software “bugs” are a good example). Those deficiencies may not be discovered for significant amounts of time and may also cause follow-on developmental efforts to slow or fail until they are finally discovered. Rework is generally a known issue for experienced project managers and was reported in some of the SAR data used in this study. Understanding the impact of the rework cycle coupled with the effects of other delay factors can provide project managers a tool to develop better schedule estimates.

Figure 6 shows a simplified, generic project with 1,000 tasks, executed by 10 people at a notional 90% productivity rate. The X-axis shows months, and the Y-axis shows the number of tasks. The graph shows both a steady reduction in work to be done, and an equally steady increase in the work completed. The graph shows completion of these 1,000 tasks at month 117.5. This representation of a CPM type schedule represents a deterministic view of a project that doesn't allow for delays or changes. This is one of the limitations of CPM and PERT and is recognized. Adding probability calculations to these schedules attempt to make them more realistic, but the root problem remains (Kerzner, 2013; Moder et al., 1983).

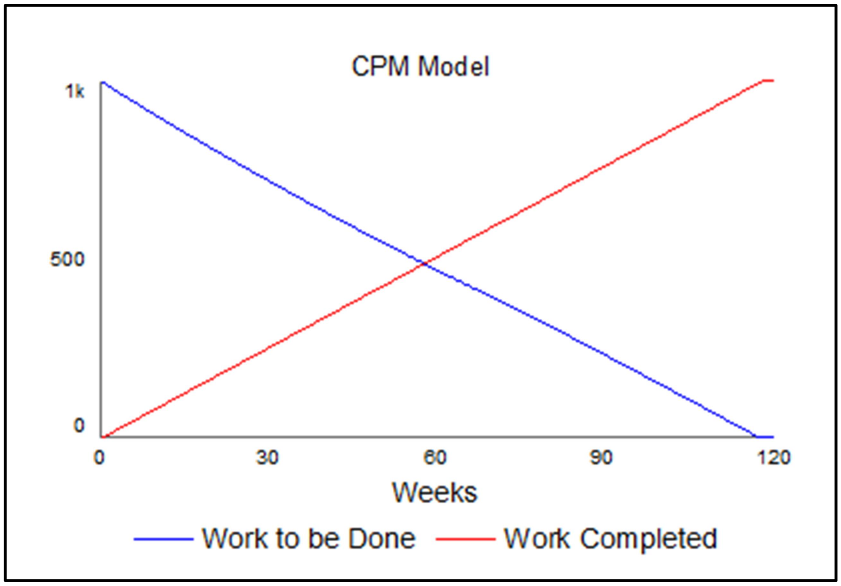

Figure 6. Model Showing the Effects of Rework

Figure 7 shows the results from the same generic model used in Figure 6, but this time incorporates the impact of the rework cycle. The X-axis shows time, and the Y-axis indicates number of tasks. Line A shows the Work Completed, line B shows Work to be Done, and line C shows a generic calculation of Rework. Comparing line A in this graph to that of work completed plot in Figure 6, demonstrates the effects of rework. In this case rework peaks at week 48 (line C) and is estimated at 75%. This means three of every four tasks must be redone, by some measures a conservative estimate especially when considering software development projects (Cooper & Mullen, 1993). Similarly, line B (Work to be Done) shows a much longer completion time than that of Figure 6. Completion time in this model run is 229 weeks, an increase of 111.5 weeks over the generic model in Figure 1, an almost 100% increase in schedule. Another way of considering the impact of rework is that instead of the 1000 tasks originally required, the number of tasks completed was 1,437—a significant increase in work requiring more time and money.

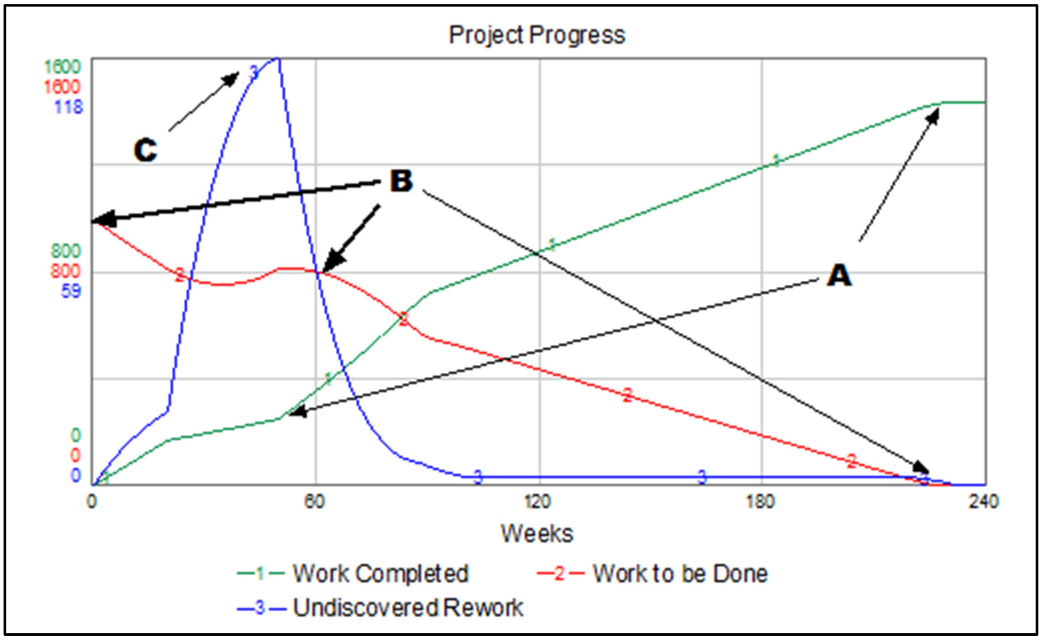

Figure 7. Model Showing the Effects of Rework

While this is an elementary model, it demonstrates that something as simple as rework can have a significant effect on project schedules.

A tool used in system dynamics to capture cause and effect is a causal map. The causal map becomes a tool used for the development of a model of the delay factors identified. Figure 8 is an initial causal loop diagram capturing some of the identified factors in weapons system program schedule delays. The factors shown are a subset of those identified for brevity in this paper.

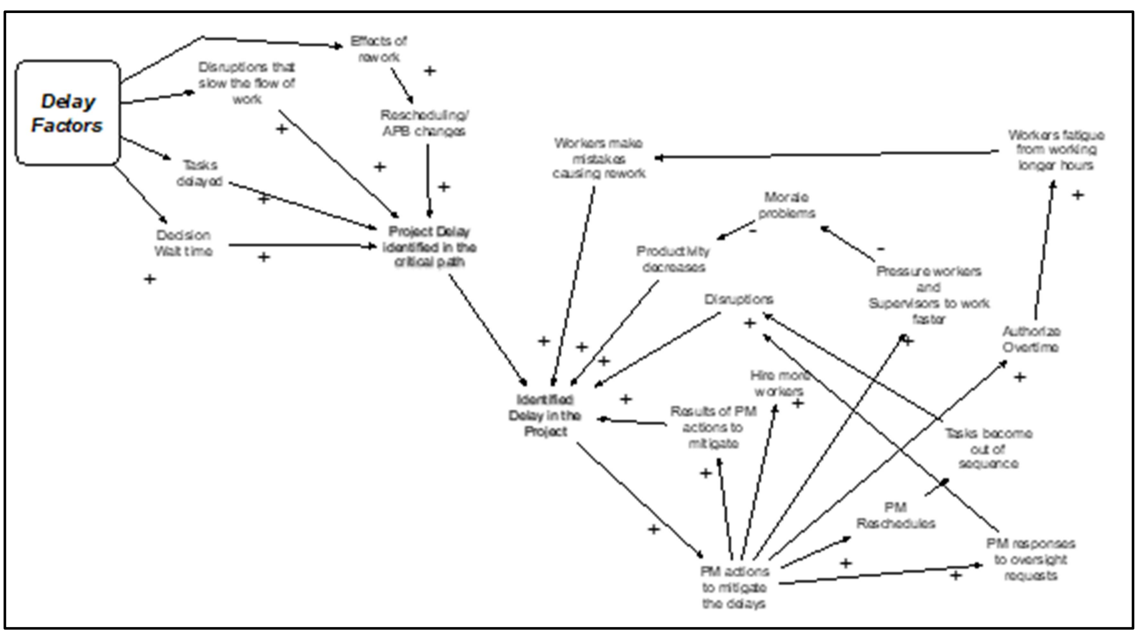

Figure 8. Delay Factors Triggers for Project Delays
(Howick, 2003)

Delay factors plus the effects of rework, decision wait time, tasks start delay, and other disruptions result in the PM (or PMO) recognizing a schedule problem (delay in the critical path). Invariably, the PM must take action to attempt to return the project to the equilibrium expressed as being on schedule. This, the PM could approve overtime, reschedule, or take some other mitigation. The pressure to get back on schedule is driven by many factors including cost considerations, pressure from the oversight organizations, and in weapons systems development, the necessity of delivering capability to the warfighter in the most efficient time. Regardless of the reason, the PM “does something.” The plus and minus signs indicate the effect of the actions taken.

The project is a dynamic system with feedback loops, and invariably decisions taken to address one problem have impact on or create new problems. For example, approving overtime does initially address schedule issues as more work is being done in shorter periods. However, a recognized problem of overtime is fatigue. Fatigue causes workers to make mistakes, and those mistakes result in having to redo the work, thus perpetuating problems that were thought solved.

Similarly, hiring more workers causes more problems. Assuming the new workers have the requisite skills, they need to be trained/ acclimated to the actual project situation. In the *Mythical Man Month*, Brooks (1995) explained how this concept works in software development. In reality, it is universal (Brooks, 1995).

Finally, while many of the delay factors identified from the SAR analysis can be explained in Figure 4, others require further examination. One of the biggest challenges is the area of decisions, both internal and external. The internal decisions drive many of the actors discussed above. However, the PM must also deal with external decisions that can eventually impact the development.

Figure 9 is a notional graphic that represents a generic decision cycle in the context of the rework cycle. While the results of this data analysis included rework, the majority of the identified delay factors were decision-focused. Those decision centric factors included represent this decision cycle. The notation is shown between the work to be done and work completed boxes because many of the decisions identified occur outside the project manager’s purview. The exogenous factors identified cause either reactions to those factors, or force other internal decisions. While not normally a part of the rework cycle, we suggest that a formal appreciation of a decision cycle, and the time it takes for decisions to be made both internal as well as external to the program management cycle must be considered.

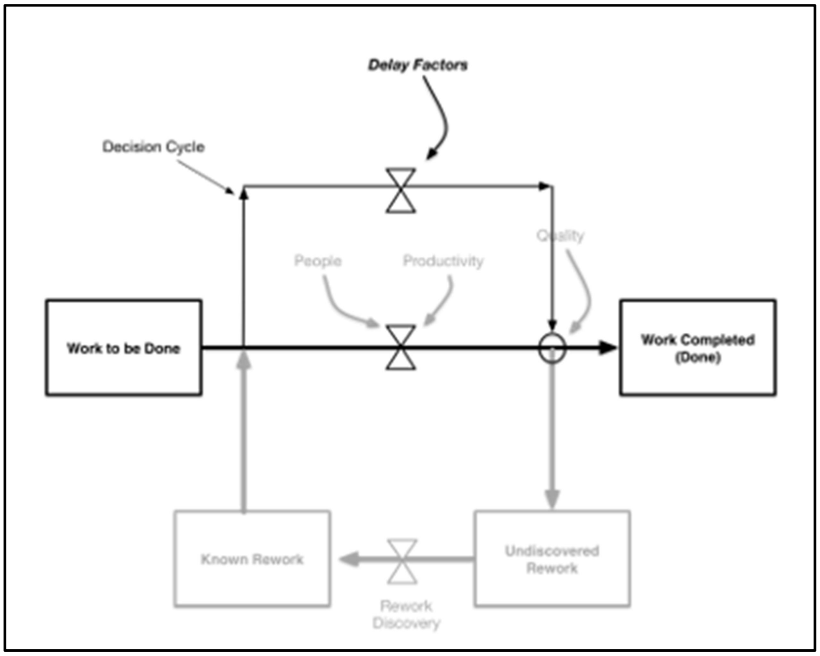

Figure 9. Notional Decision Cycle Added to Rework Cycle Diagram

Conclusion

No program manager sets out to overrun a schedule. "However, clients increasingly value not only cost and schedule control but cost and schedule certainty" (Godlewski et al., 2012, p. 18). Those clients for defense acquisition products seek certainty as well, both in cost and schedule. It is no secret that current methods for estimating and executing schedule are insufficient. In fact, certainty is one of the potential benefits of this examination of schedule factors. Project certainty starts in effective schedule planning.

This study presented a methodology to extract and identify schedule information from Selected Acquisition Reports, as well as a process for identifying classifying delay factors in weapons system acquisition programs. Finally, the study presented a suggested adjunct to the current scheduling methods that would allow project managers to use historically accurate delay factors to augment their decision processes.

This exploration of the big data aspects of defense acquisition is the first step in a continuing effort to explore not only details of schedule, but broader details and insights on the way we manage defense acquisition programs. The next step is to link the insights gained from this look at the scheduling part of the SAR to the Acquisition Program baseline (APB). The APB, oft referenced in this effort, is the vehicle to explore the entire scheduling history of an acquisition. This, we believe, could provide a better understanding of the causes of the delays by establishing a trace between results reported in a SAR, to the factor that caused the delay.

References

Balaji, J., & James, R. B. (2005). *Project dynamics with applications to change management and earned value tracking.* Presented at the System Dynamics Society International Conference.

Brooks, F. P., Jr. (1995). *The mythical man-month: Essays on software engineering* (Anniversary Ed., 2/E). Addison-Wesley.

Christensen, C. M., & Bartman, T. (2016). The hard truth about business model innovation. *MIT Sloan Management Review*.

Cooper, K. G. (1993a). The rework cycle: Benchmarks for the project manager. *Project Management Journal, 24*(1), 17–22.

Cooper, K. G. (1993b). The rework cycle: How it really works … and reworks. *PM Network*, 25–28.

Cooper, K. G. (1993c). The rework cycle: Why projects are mismanaged. Newtown Square, PA: Project Management Institute.

Cooper, K. G., & Mullen, T. W. (1993). Swords and plowshares: The rework cycles of defense and commercial software development projects. *American Programmer*.

Coyle, R. G. (1996). *System dynamics modelling*. Boca Raton, FL: CRC Press.

Drezner, J. A., & Smith, G. K. (1990). *An analysis of weapon system acquisition schedules*. Santa Monica, CA: RAND.

Franck, R., Hildebrandt, G., Pickar, C., & Udis, B. (2017). Realistic acquisition schedule estimates: A follow-on inquiry (pp. 1–20). In *Proceedings of the 14th Annual Acquisition Research Symposium*. Monterey, CA: Naval Postgraduate School.

GAO. (2015). *Acquisition reform: DoD should streamline its decision-making process for weapon systems to reduce inefficiencies* (GAO-15-192). Washington, DC: Author.

Godlewski, E., Lee, G., & Cooper, K. (2012). System dynamics transforms Fluor project and change management. *Interfaces, 42*(1), 17–32. http://doi.org/10.1287/inte.1110.0595

Hendrickson, C., Martinelli, D., & Rehak, D. (1987). Hierarchical rule-based activity duration estimation. *Journal of Construction Engineering and Management, 113*(2), 288–301. http://doi.org/10.1061/(ASCE)0733-9364(1987)113:2(288)

Howick, S. (2003). Using system dynamics to analyse disruption and delay in complex projects for litigation: Can the modelling purposes be met? *Journal of the Operational Research Society, 54*(3), 222–229. http://doi.org/10.1057/palgrave.jors.2601502

Hughes, R. T. (1996). Expert judgement as an estimating method*. Information and Software Technology, 38*(2), 67–75. http://doi.org/10.1016/0950-5849(95)01045-9

Kerzner, H. R. (2013). *Project management: A systems approach to planning, scheduling, and controlling* (11th ed.). Hoboken, NJ: Wiley.

Moder, J. J., Phillips, C. R., & Davis, E. W. (1983). *Project management with CPM, PERT and precedence diagramming* (3rd ed.). New York, NY: Van Nostrand Reinhold.

Morris, P., & Hough, G. H. (1988). The anatomy of major projects. Hoboken, NJ: John Wiley & Sons.

Project Management Institute (PMI). (2017). *A guide to the project management body of knowledge (PMBOK® Guide)—Sixth Edition and Agile Practice Guide* (ENGLISH). Newtown Square, PA: Author.

Schwindt, C., & Zimmerman, J. (2015). *Handbook on project management and scheduling* (Vol. 1). Springer.

Smith, G. K., & Friedman, E. T. (1980). An analysis of weapon system acquisition intervals, past and present (No. R-2605-DR&E/AF). Santa Monica, CA: RAND.

Van Atta, R. H., Kneece, R., Jr., Patterson, C. M., & Hermes, A. C. (2015). *Assessing weapon system acquisition cycle times: Setting program schedules*. Institute for Defense Analysis.

Williams, T., Eden, C., Ackermann, F., & Tait, A. (1994). The vicious circles of parallelism. *International Journal of Project Management, 13*(3), 151–155.

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